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A METHOD OF DETERMINING HYDROGEN PEROXIDE: AND FERROUS SALTS AND OTHER REDUCING AGENTS.

BY W. E. MATHEWSON AND J. W. CALVIN.

The fact that soluble titanium compounds give a deep yellow compound with hydrogen peroxide forms the basis of well known qualitative tests for both substances.[1] Weller's colorimetric method[2] for the estimation of titanium also depends on this reaction. The intensely yellow substance formed, usually considered to be titanium trioxide or the acid derived from it, is instantly decomposed by reducing agents and it would, therefore, seem that such compounds might be determined by titrating with standard solution of hydrogen peroxide, using a titanium salt as indicator. It was thought by the writers that if standard peroxide could be used in this way the process might be applied very advantageously in certain determinations. The peroxide is very reactive and is not only capable of acting as a strong oxidizing agent with most reducing substances, but can also reduce many of the stronger oxidizing agents and the method might be equally applicable to some reactions of the latter class. In this paper are given the results obtained with ferrous ammonium sulphate and sodium nitrite. These substances were chosen as they are well known reducing agents and seemed suitable for testing the method.

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[1] Schönn: Z. anal. Chem., **9**, 41, 330.

[2] *Ibid.*, **23**, 410, from Ber. d. chem. Ges., **15**, 2592.

Ferrous Ammonium Sulphate.—A standard, approximately 0.1 N solution of ferrous ammonium sulphate, containing some excess of ammonium sulphate was prepared, several portions of different amounts measured from a burette, about 5 cc. of phosphoric acid added, to render the solution colorless, and sufficient water to make about 50 cc. About 5 cc. of a solution of titanium potassium sulphate was then poured in and the mixture titrated at once against peroxide. The titanium solution was made by fusing the dioxide with about 10 times its weight of potassium hydrogen sulphate, dissolving the fused material in cold, dilute sulphuric acid and filtering. The results obtained from these titrations being quite concordant, 4 portions of crystallized ferrous ammonium sulphate,

$$Fe(NH_4)_2(SO_4)_2.6H_2O,$$

were weighed out, dissolved and titrated in the same way. The weights of the salt taken were 0.1985, 0.4480, 0.3405 and 0.4641 gram, respectively; the number of cc. of peroxide taken were 5.73, 12.44, 9.86 and 13.16. The amounts of hydrogen peroxide required for 1 gram of the iron salt were found, therefore, to be 28.86, 27.77, 28.96 and 28.36 cc. As ammonium sulphate is stated to make the reaction between permanganate and oxalic acid take place more smoothly and much more rapidly, it was thought that possibly the much greater irregularities observed in these results than in those with the standard solution were due to the presence of excess of ammonium sulphate in the latter. Seven portions of the Mohr's salt were again weighed out, about an equal amount of solid ammonium sulphate added, and the remainder of the operation carried out as before, except that the solution of hydrogen peroxide used was somewhat more concentrated, about 0.15 N. The following are the data obtained:

No.	Salt taken. Grams.	Peroxide required. cc.	Cc. of peroxide required per gram of salt.
1	0.1902	3.09	16.24
2	0.3420	5.54	16.19
3	0.4918	7.90	16.07
4	0.5374	8.74	16.26
5	0.6258	10.11	16.15
6	1.1133	17.82	16.01
7	1.4645	23.45	16.01

These results indicate that ferrous iron can be accurately estimated with standard hydrogen peroxide if the titre of the latter be fixed with a known amount of the same substance.

Three weighed portions of the salt were titrated against a peroxide solution and from the mean the normality of the latter was calculated. The normality was also determined by titrating against a carefully standardized permanganate solution. As the effect of slight overstepping of the end point necessary to give the liquid a tinge of color is to make the normality appear too high in the permanganate-peroxide solution, but too low in that of the iron against the peroxide, considerable care was taken to minimize this error. The titrations were made carefully and the reaction considered complete when the solution showed just a sufficient tinge of color to be recognized with certainty. The following are the data :

Titration of Peroxide against Ferrous Ammonium Sulphate.

No.	Salt taken. Gram.	Peroxide required. cc.	Cc. of peroxide required per gram of salt.
1	0.6771	11.54	17.04
2	0.5631	9.66	17.15
3	0.9563	16.23	17.02

Normality of H_2O_2 solution = 0.1498.

Titration of Peroxide against Permanganate.

10 cc. H_2O_2 solution = 13.37 cc. $KMnO_4$ solution.
25 cc. H_2O_2 solution = 33.35 cc. $KMnO_4$ solution.
Normality of H_2O_2 solution = 0.1507.

The agreement is satisfactory considering the strengths of the solutions and the quantities used. As the hydrogen peroxide solution had been prepared by diluting the ordinary pharmaceutical preparation, the slightly higher value obtained with the permanganate may have been due to the presence of traces of foreign matter. As C. E. Smith has shown,[1] commercial hydrogen peroxide sometimes yields too high results when titrated against potassium permanganate because of the presence of organic substances. Small amounts of these would probably be without influence on the results obtained with ferrous sulphate.

The above indicates a simple method for determining the strength of samples of hydrogen peroxide. The solution is diluted with a known amount of water, so that its strength is reduced to about 0.2 N (0.3 per cent). About 2 grams of ferrous ammonium sulphate are weighed out, dissolved in a little water, and a few grams of ammonium sulphate and some phosphoric acid added. Some of the titanium solution is then poured in and the mixture titrated against the peroxide, the latter being added from a burette.

Sodium Nitrite.—In these experiments solutions of sodium nitrite of about 0.5 N or 0.2 N were used. As by the action of the acid present in the indicator there is a slight loss of nitrous acid when it is first added to the solution, a rough, preliminary titration was made to determine the approximate amount of hydrogen peroxide required, then, in the subsequent titration, almost this amount was added, the indicator poured in and the titration finished. The results obtained, while reasonably concordant, have been uniformly slightly too high. This is probably due, to some extent at least, to the fact that the reaction is quite slow near the end point. Probably reasonably accurate results can be obtained only when the titre of the peroxide is fixed with a known amount of nitrite.

Work is being continued in this laboratory with a view to testing the application of the above method to the estimation of certain organic compounds, readily oxidized by hydrogen peroxide in acid or in alkaline solutions.

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[1] Chem. News, 80, 204.

Grateful acknowledgement is hereby made Prof. J. T. Willard, through whose kindness these tests have been made.

KANSAS STATE AGRICULTURAL COLLEGE.

ON A NEW METHOD FOR THE PREPARATION OF STANDARD SOLUTIONS.

BY S. F. ACREE AND R. F. BRUNEL.

The first difficulty that faces the individual beginning a series of exact volumetric analyses in acidimetry and alkalimetry is the preparation of an accurate standard solution of an acid or alkali. Among the acids used for making normal solutions by dissolving weighed amounts in the necessary quantity of water or other solvent, are potassium tetroxalate, oxalic acid and succinic acid. The chief objection to these is that they are weak acids and cannot be titrated with an error of less than 0.10 per cent. The second objection is that the first two substances cannot be made with a constant amount of water of crystallization, while if they are prepared in the anhydrous condition they do not long remain so. In solutions made from these substances by students the error may easily be 0.10–0.20 per cent.

Solutions of sulphuric and hydrochloric acids can be standardized fairly accurately by students by the barium sulphate and silver chloride methods, but this involves considerable time and care, and the barium sulphate method, especially, has several objectionable features.

In physical-chemical investigations the writers use standard solutions of hydrochloric acid and alkalies in conductivity water, which must be correct to 0.05 per cent. The standard hydrochloric acid solution is made very quickly and accurately as follows: A clean liter flask is nearly filled with conductivity water having the room temperature, and is closed with a one-hole rubber stopper through which passes a glass tube drawn out in a long capillary, reaching nearly to the bottom of the vessel.

The flask is weighed to within 0.001 gram, with a similar liter flask filled with water on the other pan. Hydrochloric acid gas, generated from fused, pure ammonium chloride and concentrated sulphuric acid and passed through two Wetzel wash-bottles containing sulphuric acid, is run into the flask until the increase in weight is a little more than a gram-molecular weight. Before the final weighing is taken the solution must be at room temperature. Very little manipulation is required to run the exact amount of hydrochloric acid desired into the flask, but even if considerably more is obtained, the solution can be made up to the required volume by filling the flask up to the liter mark and adding the required extra volume from a burette. The contraction due to mixing 12 cc. of water with a liter of normal hydrochloric acid solution is only about 0.0001 cc., or practically nothing. The method adapts itself to the preparation of any smaller volume of solution of any desired strength.

Julius Thomsen[1] tried to determine the atomic weights of hydrogen and oxygen by weighing the quantities of hydrochloric acid gas and ammonia necessary to neutralize each other. His results did not agree with those of other investigators. The reason is now apparent, as several errors were present in his work which could have been excluded.

The first source of error is that due to the absorption of moisture from the atmosphere by the calcium chloride tubes used on the flasks in which the gases were collected and weighed. This error may be quite large and it is far better not to employ such drying tubes.

The second error is that due to his method of drying the hydrochloric acid gas. Thomsen dried the gas first with concentrated sulphuric acid, the very best method possible, and then *moistened* the gas by passing it over calcium chloride or magnesium chloride. These chlorides contain considerable water of crystallization and oxides which would react with the hydrochloric acid and form water. As a result, the hydrochloric acid gas contained some moisture, which made the real amount of hydrogen chloride used smaller than it was thought to be.

The third source of error was in the method of drying the ammonia. Thomsen used potassium and sodium hydroxides in the stick form, in which considerable water is present. Fused potassium hydroxide, afterwards dried well over sulphuric acid, *in vacuo*, would have made this error very small. With these facts in view we shall repeat this work of Thomsen.

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[1] Z. physik. Chem., **13**, 398.

The normal solution made in the above way is accurate to within 0.01 per cent. The errors involved in weighing need not be more than 0.002 gram, and the moisture contained in the hydrochloric acid gas is not over 0.00005 gram, judging from the work of Dibbits.[1] Such a solution gives no precipitate with barium chloride, is practically free from carbon dioxide, silicates and all other impurities which are present in the best hydrochloric acid sold in the market. This fact is of the very highest importance to those using such standard solutions for very exact titrations or in physical-chemical investigations involving conductivity measurements. By this method a standard acid solution can be made very quickly, and its error is far smaller than that of the ordinary titration process; it can, therefore, be used directly for titration against alkalies without further standardization. The solution keeps a long time.

In the same way standard solutions of any dry gases, such as hydrogen bromide, hydrogen iodide, hydrogen sulphide, sulphur dioxide, ammonia, chlorine, etc., in any solvent, can be prepared. The writers use this method for making standard alcoholic hydrochloric acid solutions.

For determining the strength of solutions of pure hydrochloric and sulphuric acids the following plan is much better than the silver chloride and barium sulphate methods. Sodium bicarbonate was crystallized twice and was then free from chlorides, sulphates and silicates. Approximately 4.12 grams of this were put into a tall beaker, covered with a watch-glass having a hole in the center and titrated with the necessary volume, or weight of normal acid—about 50 cc. For very accurate titrations the carbon dioxide should be removed from the solution in a vacuum, the end point being obtained when the faintly pink solution remains unchanged in color after standing in a vacuum for some time. The solution is then evaporated to dryness in a weighed platinum dish and heated to dull redness, until the sodium chloride is dry and the weight constant. A similar platinum dish is treated in the same way and used as a tare. From the weight of the sodium chloride or sodium sulphate and the volume or weight of the acid solution used, the strength of the latter can be easily determined. The total errors of this method should not be more than 0.05 per cent. The titration error should not be over 0.01 cc. in 50 cc., or 0.02 per cent, and the weighing error not more than 0.01 per cent. The method can be used for the determination of the strength of a solution of any acid whose sodium salt can be dried and weighed accurately. The titration error is larger with weaker acids.

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[1] Z. anal. Chem., 15, 121.

In a similar manner the exact strength of a solution of pure sodium or potassium hydroxide can be determined by evaporating an exact amount, approximately 50 cc., with pure hydrochloric acid. The weight of the chloride obtained and the volume or weight of the alkali solution give the data necessary for determining the strength of the alkali solution. The unknown strengths of an acid solution and of an alkali solution can be determined simultaneously by neutralizing 50 cc. of the acid solution with the necessary amount of the alkali solution and evaporating the mixture to dryness, as above. The weight of the dry salt and the volumes of acid and alkali solutions taken furnish the necessary data. The solutions of acid and alkali must be free from appreciable quantities of silicates, chlorides, sulphates or other impurities.

Special experiments by Mr. G. H. Shadinger showed that methyl orange is much more sensitive to carbonic acid than is popularly supposed. When carbon dioxide, purified by being passed through two Geissler potash bulbs containing sodium bicarbonate solution, was run into a solution of 3 grams of sodium chloride, in 50 cc. of water containing a drop of 1 : 2000 solution of methyl orange, the pink color produced was discharged by 0.06–0.40 cc. of 0.1 N potassium hydroxide. Further experiments showed that these solutions, made pink by carbon dioxide, correspond in color to similar solutions made pink by 0.06–0.20 cc. of 0.1 N hydrochloric acid, the intensity of the color varying with the degree of saturation of the solution with the carbon dioxide. When these solutions, saturated with the gas, are vigorously stirred and shaken, as in a titration experiment, the pink color corresponds to that produced by 0.06–0.10 cc. 0.1 N hydrochloric acid under the same conditions. Solutions made pink by carbon dioxide become brown very quickly in a vacuum, whereas similar solutions made pink by hydrochloric or sulphuric acid are not changed in color by such treatment. It is, then, very probable that analyses of carbonates by standard acids in the presence of methyl orange, as ordinarily made, are undertitrated, and the per cent of carbonate found is too low.

Standard Hydrochloric Acid Solutions.

By the method described above, a hydrochloric acid solution was made up to be 0.99987 N. The molecular weight of hydrochloric acid was taken to be 36.458. If the molecular weight 36.471, found by Dixon and Edgar,[1] which is a mean between the values found by Stas and by Richards and Wells,[2] were used, the acid would be 0.99953 N.

This solution was analyzed by the sodium bicarbonate method described above, but the carbon dioxide was not completely removed from the solutions. This error, however, was nearly compensated by the use of the value 23.05 for the atomic weight of sodium instead of 23.01, an error of 0.08 per cent of the weight of sodium chloride. The hydrochloric acid was measured from very carefully calibrated burettes. Three analyses are given in the following table:

Volume of HCl solution. cc.	Weight of NaCl. Grams.	Strength of HCl solution.
30.30	1.7730	1.0002 N
30.50	1.7833	0.99937 N
47.24	2.7629	0.99976 N

Average = 0.99972 N, or 0.015 per cent low.

These results show that solutions of hydrochloric acid, prepared as above, are as accurate as any ordinary analytical work requires. The writers believe that the sources of error noted above could be further reduced so that the method would serve for determining the ratio of the atomic weights of chlorine and sodium. For a number of years the value 23.05, obtained by Stas, has been generally accepted, but the recent very accurate work of Richards and Wells gives the value 23.01. If the total errors in the above method can be reduced to 0.02 per cent the writers believe it will furnish reliable evidence in favor of one or the other of the above values for sodium.

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[1] Chem. News, **91**, 263.

[2] J. Am. Chem. Soc., **27**, 459.

A further example of the accuracy and convenience of the sodium bicarbonate method for estimating the strength of acid solutions is given. A normal solution of sulphuric acid was made volumetrically through two other solutions, using about 15 cc. in the titrations. The titration error might then be about 0.20 per cent. This solution was analyzed by the barium sulphate method, the error being not more than 0.10 per cent; 20.68 cc. gave 2.4170 gram $BaSO_4$, or the solution was 1.0013 N. It was then analyzed by the sodium bicarbonate method, under the conditions given above, with the following results:

Volume of H_2SO_4 solution. cc.	Weight of Na_2SO_4. Grams.	Strength of H_2SO_4 solution.
47.32	3.3722	1.0026 N
45.33	3.2290	1.0022 N
		Mean = 1.0024

If this last value be considered accurate, the results found by the different methods check very satisfactorily. From the titrations the acid appeared to be exactly normal, but there was a possibility of 0.20 per cent error. The barium sulphate method, with a possible source of error of 0.10 per cent, gave a result 0.11 per cent below that obtained by the bicarbonate method.

Standard Ammonium Hydroxide Solutions.

An attempt was made to prepare standard ammonium hydroxide solutions by passing the dried gas into water in a weighed flask, under conditions similar to those employed in the preparation of standard hydrochloric acid. The concentrated commercial ammonia solution was treated with lime water to remove the carbonates ; it was then warmed gently in a flask and the gas was dried by passing it through towers containing quicklime and potassium hydroxide in sticks, and finally through a glass tube 6 feet in length, filled with broken potassium hydroxide, which had been fused and dried over concentrated sulphuric acid. The gas was then practically free from carbon dioxide and moisture,[1] and probably contained very little pyridine.

Several attempts to prepare solutions about 0.2–0.5 N showed that such solutions lose ammonia very quickly when exposed to the air, or when transferred to other vessels. That the method could be relied upon to give standard solutions was proved conclusively ; such solutions, however, will not remain long unchanged.

A solution was made by passing 1.2450 grams of ammonia into 250 cc. of water ($N = 14.04$, $H = 1.008$). This solution was then 0.29184 N. It was analyzed as follows : Normal hydrochloric acid solution, nearly sufficient to neutralize 50 cc. of the above ammonium hydroxide solution, was run into a beaker. The ammonium hydroxide solution was removed from the flask by means of a 50 cc. pipette containing a small layer of ligroin to prevent the escape of ammonia, and the solution was immediately allowed to run into the hydrochloric acid solution, the point of the pipette being immersed.

Two analyses showed 50 cc. of the ammonium hydroxide solution to be equivalent to 14.58 and 14.58 cc. of normal hydrochloric acid ; calculated, 14.59 cc. The strength of the ammonium hydroxide was 0.2916, or the error in the method was 0.07 per cent.

These standard solutions of hydrochloric acid and ammonium hydroxide are sufficiently accurate to warrant us in believing that the principle of using weighed quantities of well-dried gases for making up standard solutions is one worthy of further study, and this will be done in the near future.

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May 1, 1906.

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[1] Van der Plaats : Rec. Trav. Chim., 6, 45.

ON THE CONSTITUTION OF AMALGAMS.

[PRELIMINARY COMMUNICATION.]

By George McPhail Smith.

As the result of investigations by Ramsay, Heycock and Neville, Tammann, and G. Meyer on dilute solutions of metals in other metals, it is generally accepted as a fact that, in solution, as a rule, the metals exist in the same state of aggregation as in the gaseous form ; *i. e.*, that in solution the atom of a metal is identical with its molecule.[1]

According to this prevailing view, it is tacitly assumed that the metals, as a rule, dissolve as such in other metals. This, however, is not necessarily the case and, just as among solid alloys we have the two classes, chemical compounds and mechanical mixtures to deal with, so it appears possible, if not probable, that liquid solutions of metals in metals may also comprise these two classes of substances.

It is the purpose of the present paper to discuss, from the above point of view, the results of Ramsay, Tammann and others; especially with reference to the constitution of the liquid alkali amalgams.

In 1879 Berthelot[2] published the heats of formation of potassium and sodium amalgams, and showed that, in these amalgams, the solution of the alkali metal in mercury considerably lowers the heat of oxidation of the former. Indeed, in the analogous amalgams, KHg_{12} and $NaHg_6$, the heat of oxidation of potassium is less than that of sodium, the values for the two alkali metals in these amalgams being of an inverse order as compared with those for the metals themselves.

Berthelot found that the amalgam $NaHg_6$, on being dissolved in 3 times its weight of mercury, absorbed —2.8 cal., and —2.9 cal. on being dissolved in 18 parts of mercury at 17°. These numbers agree well with one another, and they approach in value the heat of fusion (—3.36 cal.) of the mercury in the amalgam—a relation that is found to exist between the heat of solution of the highest hydrated salts and the heat of fusion of the water contained in them. From this and other data, Berthelot concluded that these amalgams were compounds analogous to hydrated salts.

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[1] Kerp: Z. anorg. Chem., **17**, 286f (1898). Schoeller: Z. elek. Chem., **5**, 259 (1898). Erdmann: Z. anorg. Chem., **32**, 404 (1902). Ostwald: "Lehrbuch" I., pp. 737, 767; II., i., pp. 859, 862 (1903).

[2] Ann. Chim. Phys., [5], **18**, 433.

More recently Kerp and Böttger,[1] Maey,[2] Guntz and Ferée,[3] Kurnakoff,[4] and Haber and Sack[5] have investigated the amalgams of the alkalies and alkaline earths, and have established beyond a doubt the existence of definite compounds among them. Kerp and Böttger follow Berthelot in considering the crystalline alkali amalgams, such as $NaHg_6$ and KHg_{12}, as analogous to hydrated salts, *i. e.*, as being made up of a fundamental compound of mercury and alkali metal, combined with various amounts of mercury of crystallization.

Guntz and Ferée[6] found that, when a solution of sodium in mercury is allowed to crystallize at —19°, crystals of $NaHg_8$ separate. These, on coming to the room temperature, break up into $NaHg_6$ and liquid amalgam. Similarly, Kerp and Böttger[6] found that, on heating $NaHg_5$, it breaks up into a crystalline amalgam richer in alkali and liquid amalgam.

The liquid amalgams, however, are regarded by Kerp and Böttger as being solutions of sodium or potassium in mercury, in the atomic state.[7]

Haber and Sack,[8] on the other hand, clearly express their conviction that sodium does not dissolve in mercury in the monatomic condition. They say: "Als beweisend für dieselbe werden die Meyer'schen Messungen für Amalgam-Konzentrationsketten angesehen. Aber deren Ergebnis erlaubt keine Entscheidung darüber, ob das Natrium in Atomform oder in Gestalt der Verbindung Hg_5Na oder überhaupt Hg_nNa im Quecksilber sich befindet. Sie lehren nur, dass es weder als Na_2, noch in einer Verbindung Hg_nNa_2 darin auftreten kann. Ramsay's Autorität kann zu gunsten der Einatomigkeit des Natriums im Quecksilber keine Instanz abgeben, denn seine Dampfdruckerniedrigungen sind gerade bei diesem Metall anormal und er erörtert selbst die Möglichkeit, dass Legierungen auftreten. Sodann arbeitete Ramsay bei 270°,[1] also bei einer Temperatur, wo Umwandlungen der Amalgame andere Zustände als bei Zimmertemperatur schaffen. Es muss, unseres Erachtens, als die best begründete Auffassung angesehen werden, dass die verdünnten Natriumamalgame bei gewöhnlicher Temperatur Lösungen von Hg_6Na und Hg_5Na in Quecksilber sind."

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[1] Z. anorg. Chem., **17**, 284 (1898); **25**, 1 (1900).

[2] Z. physik. Chem., **29**, 119 (1899).

[3] Compt. rend., **131**, 182 (1900).

[4] Z. anorg. Chem., **23**, 439 (1900).

[5] Z. elek. Chem., 8, 245 (1902).

[6] *Loc. cit.*

[7] *Loc. cit.*, **17**, 286f.

[8] *Loc. cit.*, p. 255.

It will be shown, in the following, that Ramsay's results, as well as those of Heycock and Neville, and of Tammann, do not necessarily indicate the presence in solution of metals in the atomic state; they are just as well in harmony with the presence of compounds in solution. This, as is seen from the preceding quotation, completely escaped Haber's notice; even if Ramsay's results for sodium had been normal, they would not necessarily have indicated its presence in the atomic condition. That the same holds in the case of the measurements of G. Meyer has already been pointed out by Haber.[2]

In 1889, Ramsay[3] determined the vapor pressures, at the boiling point of mercury, of a series of dilute solutions of metals in mercury. In every case he observed a lowering of the vapor pressure, due to the presence of the metal in solution. From his results he calculated the molecular weights of the dissolved metals, as shown in the following abbreviated table where $s =$ the weight of metal dissolved in one gram-molecule, *i. e.*, in 200 grams of mercury; $p =$ the pressure of mercury vapor in mm; $p - p_1 =$ the observed depression in mm.

In his table, Ramsay used the per cent, P, of the dissolved metal in the solution, instead of the amount of metal dissolved in 100 grams of mercury. From P in his table, the values of

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[1] Ramsay really worked at the boiling point of mercury.

[2] Z. physik. Chem., 41, 399 (1902).

[3] J. Chem. Soc., **55**, 521.

$\frac{1}{2}s$ have been calculated. The molecular weights found are practically the same in both cases.

Table I.

	Weight of metal in 100 grams of mercury. $\frac{1}{2}s$.	Atoms of metal per 100 atoms of mercury.	p.	$p-p_1$.	Molecular weight found. $\frac{sp}{p-p_1}$.	Atomic weight.
Lithium	0.05973	1.70	763.6	12.9	7.07	7.03
Sodium	0.21516	1.87	766.8	17.9	18.4	23.05
Potassium	1.0285	5.26	742.5	49.6	30.8	39.15
Barium	0.61445	0.90	762.0	12.3	76.1	137.4
Magnesium	0.58541	4.82	749.8	40.6	21.6	24.36
Zinc	1.0319	3.16	755.4	23.6	66.0	65.4
Cadmium	1.9596	3.51	740.0	27.4	105.8	112.4
Aluminum	0.39657	2.94	758.5	18.1	33.2	27.1
Gallium	0.79171	2.27	767.1	17.3	70.2	70.70
Thallium	1.6942	1.66	745.6	13.3	190.0	204.1
Tin	1.1552	1.94	754.1	14.7	118.5	119.0
Lead	2.0616	2.00	762.1	15.4	204.0	206.9
Antimony	1.5497	2.58	742.6	14.3	160.9	120.2
Bismuth	3.9198	3.77	762.1	26.8	222.9	208.5
Manganese	0.31318	1.14	755.0	8.5	55.6	55.0
Silver	1.7387	3.22	750.0	22.8	114.4	107.93
Gold	1.5651	1.59	760.4	11.3	211.6	197.2

On inspecting the table it will be seen that the molecular weights found for many of the metals are expressed by numbers very closely approximating to their atomic weights. For some of the metals, however, the numbers do not agree very well.

The molecular weight of a substance, in dilute solution, may be calculated from the formula

$$\text{Mol. wt.} = \frac{M.\frac{1}{2}s.p}{100(p-p_1)},$$

in which M is the molecular weight of the solvent, and the other letters have the same significance as in the preceding table. In this formula, the observed depression ($p-p_1$) depends only upon the number of molecules of the dissolved substance in a given quantity of the solvent, hence this depression would be practically the same, whether a given, very small weight of lithium, for example, were dissolved in a given, relatively very much greater quantity of mercury, in the form of lithium atoms, or in the form of molecules of a compound, $LiHg_n$, containing only one atom of lithium to the molecule. That this actually is the case may be seen from the following table, which has been calculated from the preceding one, and in which only those metals have been included which are known to form compounds with mercury. In Table II. $m =$ the weight of compound dissolved in 100 grams of mercury. It was obtained from $\frac{1}{2}s$ in the preceding table, according to the formula

$$m = \frac{\dfrac{\frac{1}{2}s \text{ . mol. wt. of } MHg_n}{\text{at. wt. of } M} \text{ . } 100}{100 - \left(\dfrac{\frac{1}{2}s \text{ . mol. wt. of } MHg_n}{\text{at. wt. of } M} - \frac{1}{2}s\right)}.$$

Table II.

	m.	Molecules of compound per 100 atoms of mercury.	p.	$p-p_1$.	$\frac{2m \, . \, p}{p-p_1}$.	Molecular weight.
LiHg	1.7896	1.73	763.6	12.9	211.8	207.03
$LiHg_3$	5.4490	1.79	763.6	12.9	645.1	607.03
$LiHg_5$	9.3515	1.86	763.6	12.9	1107.1	1007.03
$NaHg_2$	4.1021	1.94	766.8	17.9	351.4	423.05
$NaHg_6$	12.857	2.10	766.8	17.9	1101.5	1223.05
KHg_2	12.891	5.87	742.5	49.6	385.9	439.15
KHg_4	27.910	6.65	742.5	49.6	835.6	839.15
KHg_6	47.642	7.68	742.5	49.6	1426.4	1239.15
$BaHg_{12}$	12.711	1.00	762.0	12.3	1575.0	2537.4
MgHg	5.6639	5.05	749.8	40.6	209.2	224.36
$MgHg_6$	41.346	6.78	749.8	40.6	1527.2	1224.36
AgHg	5.1258	3.33	750.0	22.8	337.2	307.93

With regard to the existence of the compounds enumerated above, reference may be made, in addition to the papers already cited, to the work of Schüller[1] and Ogg[2]. The compound $MgHg_6$ is described by Kerp and Böttger,[3] but MgHg is not mentioned in the literature. Magnesium amalgams, however, have not been investigated to any extent.

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[1] Z. . anorg. Chem., 40, 385 (1904).

[2] Z. physik. Chem., 27, 285 (1898).

[3] *Loc. cit.*

On comparing the two tables, it will be seen that the values found for LiHg and AgHg in the second table agree with their theoretical molecular weights about as well as those found for Li and Ag in the first table agree with their atomic weights. Values found for compounds of sodium, potassium and barium with mercury agree better than those for the metals themselves; but the number found for $MgHg_2$ does not agree so well. For the compound MgHg, however, whose existence is not improbable, the values are in good agreement. The crystalline amalgams, $NaHg_2$ and KHg_2, melt without decomposition at 346° and 269°.7, respectively. Solid sodium and potassium amalgams richer in mercury are decomposed by heat into free mercury and a crystalline amalgam richer in alkali metal, Cf. Kurnakoff[1] and Schüller.[1]

On the other hand, Puschin,[2] in order to determine whether mercury forms compounds with zinc, cadmium, bismuth, lead and tin, has investigated the melting curves, the electromotive forces, and the microstructure of the amalgams of the metals in question. His results lead to the conclusion that the amalgams of these metals correspond to solid solutions or isomorphous mixtures, and that the assumption of the existence of definite chemical compounds in their case, as given by various authors,[3] has no experimental foundation. Bijl[4] had previously reached the same conclusion in regard to cadmium amalgam. Since the values found for these metals by Ramsay agree very well with their atomic weights, we are, perhaps, justified in concluding that they exist, when dissolved in mercury, in the atomic condition.

In a series of measurements, similar to those of Ramsay, Tammann[5] made use of the cryoscopic method. He employed mercury as a solvent and obtained the results in Table III., where m = the weight of metal dissolved in 100 grams Hg; n =

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[1] *Loc. cit.*
[2] Z. anorg. Chem., **36**, 201 (1903).
[3] Cf. Puschin: *Loc. cit.*
[4] Z. physik. Chem., **41**, 641 (1902).
[5] *Ibid.*, **3**, 441 (1889).

atoms of metal per 100 atoms of mercury ; $t-t_1$ = the depression of the freezing point of mercury.

Table III.

	m.	*n*.	$t-t_1$.	Molecular weight found. $\frac{425 \cdot m}{t-t_1}$.	Atomic weight.
Potassium	0.018	0.092	0.27	28.4	39.15
"	0.030	0.147	0.42	30.4	"
"	0.091	0.448	0.73	53.0	"
"	0.112	0.552	1.04	45.8	"
"	0.137	0.676	1.24	46.9	"
Sodium	0.022	0.191	0.39	24.0	23.05
"	0.043	0.374	0.72	25.4	"
"	0.112	0.974	2.23	21.3	"

On the assumption that the compounds KHg_{12} and $NaHg_6$[1] were present in Tammann's solutions, the following table has been calculated :

Table IV.

	m.	*n*.	$t-t_1$.	$\frac{425 \times m}{t-t_1}$.	Molecular weight.
KHg_{12}	1.1340	0.093	0.27	1785	2439.15
"	1.9041	0.156	0.42	1927	"
"	6.0046	0.492	0.73	3496	"
"	7.4923	0.614	1.04	3062	"
"	9.3182	0.764	1.24	3194	"
$NaHg_6$	1.1809	0.192	0.39	1287	1223.05
"	2.3339	0.379	0.72	1377	"
"	6.3109	1.026	2.23	1203	"

Tammann says his measurements are only of an orientating character ; they do vary greatly among themselves. The mean found for potassium is 40.9 instead of 39.15, and for sodium it is 23.57 instead of 23.05. The above table gives for KHg_{12} a mean of 2693 instead of 2439.15, and for $NaHg_6$ 1289 instead of 1223.05. These values agree within the error of experiment.

In two series of cryoscopic measurements, much more elaborate than those of Tammann, Heycock and Neville[2] used as solvents sodium and tin. Their results, for the first series, are given in a modified form in the following table. Heycock and Neville expressed their results in terms of the atomic fall, *i. e.*, the fall produced in the freezing point of the pure solvent by dissolving one atomic weight of metal in 100 atomic weights of sodium. Numerous experiments were performed in the case of each dissolved metal and, in the preparation of the above table, the experiment under each metal has been selected in which the mean atomic fall found in that series was most nearly approximated. In Heycock and Neville's tables this was for gold (6), for thallium (6), for mercury (5), for cadmium (7), for potassium (3) and for lithium (2).

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[1] Cf. Kerp and Böttger : *Loc. cit.* **25**, 1.

[2] J. Chem. Soc., **55**, 666 (1889) ; **57**, 376 (1890).

The molecular weight of a dissolved substance is obtained from the equation $M = \frac{D\ .\ m}{t—t_1}$. Assuming the molecular weight of gold to be identical with its atomic weight, we have, $197.2 = \frac{D\ .\ 8.267}{4.38}$, whence D = the molecular depression of the freezing point, in the case of sodium = 104.5.

Table V.

	Weight of metal per 100 grams Na. m.	Atoms of metal per 100 atoms Na. n.	$t - t_1$.	$\frac{104.5\ .\ m}{t - t_1}$.	Atomic weight.
Gold	8.267	0.965	4.38	197	197.2
Thallium	9.558	1.033	4.41	226	204.1
Mercury	7.368	0.847	3.83	201	200.0
Cadmium	2.649	0.544	1.95	142	112.4
Potassium	2.185	1.288	4.61	49.5	39.15
Lithium	0.3658	1.2	1.59	24	7.03
Li_3	0.3658	0.4	1.59	24	21.09

From the preceding table, the following one has been calculated for the more or less well-known compounds of the dissolved metals with sodium. These compounds are described in the following papers: NaTl, Kurnakoff and Puschin;[1] NaHg and Na_3Hg, Kurnakoff[2] and Maey;[3] the existence of

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[1] Z. anorg. Chem., **30**, 86 (1902).

[2] *Ibid.*, **23**, 439 (1900).

[3] *Loc. cit.*

NaK_2 is maintained by Joannis,[1] while Kurnakoff and Puschin[2] deny it and assert instead the existence of a compound of either the formula Na_2K or Na_3K_2. The values found above do not agree for potassium itself, or for any of these compounds. The compound $NaLi_3$ is not mentioned in the literature. Its existence, however, would seem more probable than that of triatomic lithium molecules.

Table VI.

	m.	n.	$t-t_1$.	$\frac{104.5 \cdot m}{t-t_1}$.	Molecular weight.
NaTl	10.751	1.091	4.41	255	227.1
NaHg	8.285	0.856	3.83	226	223.0
Na_3Hg	10.173	0.871	3.83	277	269.1
NaK_2	2.847	0.647	4.61	64.5	101.3
Na_2K	4.883	1.324	4.61	110.7	85.2
Na_3K_2	4.196	0.656	4.61	95.1	147.4
$NaLi_3$	0.7686	0.401	1.59	50.5	44.1

Heycock and Neville's experiments were made as follows: Solid paraffin was first placed in the crucible and, as soon as it was melted, a weighed quantity of sodium (from 20 to 30 grams, in large sticks) was dropped in, the molten paraffin forming a layer above the sodium. The melting point of the sodium was then determined, after which small, weighed quantities of metal were added in succession. The melting point of the solution was determined after each addition.

From the last two tables it will be seen that their results do not indicate the non-existence of compounds of sodium with the dissolved metal. That Heycock and Neville did not realize this fact is shown by the following quotation:[3]

"When mercury was added to the molten sodium, a considerable evolution of heat and light took place. It is worthy of note that the atomic falls do not indicate in any way the formation of a chemical compound as might be anticipated. Had the mercury after addition appropriated a portion of the solvent, it should have made these atomic falls (?) increase as the number of atoms of solvent diminished. It seems not unreasonable to suppose that a compound may be formed at first and dissociated afterwards through the great dilution of the solution." Such a dissociation appears highly improbable.

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[1] Ann. Chim. Phys., [6], **12**, 358 (1887).

[2] Z. anorg. Chem., **30**, 109 (1902).

[3] *Loc. cit.*, **55**, 671.

That the metals dissolve in each other in the atomic condition was, apparently, further confirmed by the experiments of G. Meyer,[1] who measured the electromotive force of the combination :

Concentrated amalgam | solution of a salt of the dissolved metal | dilute amalgam.

From his results he calculated the molecular weight of the metal dissolved in mercury, by means of the equation

$$\pi = 0.002\,\frac{T}{n}\log\frac{c_1}{c_2},$$

in which π = the electromotive force, T = the absolute temperature, n = the number of electrical units transported by one molecular weight of the metal in the form of ions, and c_1 and c_2 = the concentrations of the respective amalgams. By dividing n by the number of electrical units which go with one atom of the metal in question, Meyer calculated the number of atoms in the molecule and thence the molecular weight. For the metals investigated, *viz.* zinc, cadmium, lead, tin, copper and sodium, values were obtained which agree with their atomic weights. Barium was investigated by Schoeller[2] with the same result.

The formula of G. Meyer holds only when the dissolved metal, which must be more electropositive than mercury, exists as such in the latter. It does not apply to metals which form compounds with the mercury. In the case of sodium which, at ordinary temperatures, exists in solution as $NaHg_6$, Haber[3] has shown that the formula

$$\pi = 0.002T\left[\log\frac{c_1}{c_2} + 23.0\,(c_1 - c_2)\right]$$

is applicable, and in his paper he demonstrates that the values experimentally obtained by Meyer in the case of sodium agree as well with the one formula as with the other. The results of Meyer's measurements for sodium amalgams are given here, together with the calculated values:

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[1] Z. physik. Chem., **7**, 447 (1891).

[2] Z. elek. Chem., **5**, 259 (1898).

[3] Z. physik. Chem., **41**, 399 (1902).

			Found.	Calculated.	
T.	c_1.	c_2.	Volt.	Meyer.	Haber.
293.2	0.0003325	0.0000953	0.0327	0.0315	0.0318
291.5	0.0002820	0.0000982	0.0248	0.0265	0.0267
285.0	0.0002282	0.0001006	0.0174	0.0196	0.0198

Almost simultaneously with Meyer's investigation, there appeared a theoretical paper by V. von Türin,[1] in which was discussed the possibility of determining the molecular weights of metals dissolved in mercury, by measuring the electromotive force of the combination:

Mercury | solution of a mercurous salt | amalgam.

In this case the mercury is the transport metal, and equilibrium cannot be attained until all the mercury has dissolved and migrated to the amalgam. This, of course, presupposes that the salt of mercury shall not be acted upon by the amalgam; *i. e.*, that the dissolved metal is more electronegative than mercury. This method, in connection with which, owing to the difficulty in procuring a suitable salt of mercury,[2] we have no experimental data, is fully analogous to the vapor-pressure method for determining molecular weights. In the latter case we have a depression of the vapor pressure, due to the dissolved metal, while in Türin's combination we have a depression of the solution pressure, due to the same cause.[3] The method of Türin, like the vapor-pressure method, furnishes us with a possible means of determining, in the general formula M_nHg_m, the value of *n*. The value of *m* might, or might not be zero.

In this connection it may be mentioned that Coehn[4] has recently prepared ammonium amalgam by the electrolysis of ammonium sulphate at 0°. The amalgam obtained at this temperature became only slightly inflated, and it retained its metallic appearance. Coehn showed that this amalgam is capable of precipitating copper, cadmium and zinc from well-cooled solutions of their sulphates, and thus established, beyond a doubt, that ammonium is capable of forming a true amalgam. The existence of free ammonium, or of di-ammonium, in this amalgam is, however, hardly to be assumed. We probably have to do here with a compound of mercury and ammonium, which, judging from the analogy that elsewhere exists between potassium and ammonium, probably has the formula $(NH_4)Hg_{12}$. At temperatures between 0° and 71° the compound KHg_{12} is stable.[1]

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[1] Z. physik. Chem., **5**, 340 (1890).

[2] Cf. Meyer: *Loc. cit.*

[3] Cf. Ostwald: "Lehrbuch," II., i, 863 (1903).

[4] Z. anorg. Chem., **25**, 430 (1900).

Summary.

It has been shown, in the foregoing, that the methods for determining molecular weights which have been discussed do not furnish us with a means of deciding whether, in an amalgam or alloy, the dissolved metal is present as such, or in combination with the solvent. In the general formula M_nHg_m, these methods permit of the determination of n, but the degree of accuracy so far attained by these methods is not sufficient for determining the exact magnitude of m.

There is every evidence for the existence of many definite chemical compounds of mercury with the metals of the alkali and alkaline earth groups, and there is no reason to suppose that these compounds break up on being dissolved in mercury. The liquid amalgams of the metals of these two groups are solutions in mercury of compounds of the general formula MHg_m, containing only one atom of the amalgamated metal to the molecule.

In those cases in which we have good evidence for the non-existence of compounds of mercury with the dissolved metal, we are justified in concluding that the metal is dissolved, as such, in the mercury. This is the case with zinc, cadmium, bismuth, lead and tin and, according to the measurements of Ramsay, these metals exist, when dissolved in mercury, in the form of monatomic molecules.

UNIVERSITY OF ILLINOIS,
April 23, 1906.

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[1] Kerp and Böttger: *Loc. cit.*

Contributions from the Sheffield Laboratory of Yale University.

CXXXI.—RESEARCHES ON PYRIMIDINES: THE ACTION OF POTASSIUM THIOCYANATE UPON IMIDE CHLORIDES.

[FIFTEENTH PAPER.]

BY TREAT B. JOHNSON AND ELMER V. McCOLLUM.

We shall describe in this paper a new case of the molecular rearrangement of a thiocyanate, I., to an isothiocyanate, II., which is unique for this type of metamerism.

$$\underset{\text{I.}}{RSCN} \rightarrow \underset{\text{II.}}{RNCS}.$$

In the acyclic series an unsaturated condition in the 2,3-position

$$\underset{3}{C} : \underset{2}{C}\underset{1}{C}$$

is favorable for the formation of isothiocyanates. For example: Allyliodide, III., and 1,2-dichlorpropylene,[1] IV., when heated with potassium thiocyanate, react to form the corresponding isothiocyanates, according to the following equations:

$$\underset{\text{III.}}{CH_2 : CHCH_2I} + KSCN = KI + CH_2 : CHCH_2SCN \rightarrow CH_2 : CHCH_2NCS;$$

$$\underset{\text{IV.}}{CH_2 : CClCH_2Cl} + KSCN = KCl + CH_2 : CClCH_2SCN \rightarrow CH_2 : CClCH_2NCS.$$

Such groupings, so far as examined, do not permit of the isolation of the primary products—thiocyanates—except when heat is avoided.

In a recent publication from this laboratory, Wheeler and Bristol[2] have described the behavior of some cyclic imide chlorides towards potassium thiocyanate. Since such chlorides, V., are closely related to acid chlorides, VI., and the cyclic

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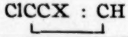
[1] Wheeler and Merriam: J. Am. Chem. Soc., 23, 287.

[2] THIS JOURNAL, 33, 448 (1905).

$$—CCl : NR, \qquad —CCl : O,$$

V. VI.

derivatives examined contain an unsaturated 2,3-position, VII.,

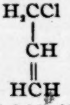


$ClCCX : CH$

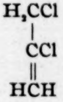
VII.

it seemed probable that isothiocyanates would result if such halides were treated with potassium thiocyanate.

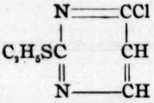
Their experimental data supported this assumption. They observed that 2-ethylmercapto-6-chlorpyrimidine, VIII., 2-ethylmercapto-5-brom-6-chlorpyrimidine, IX., and 2-ethylmercapto-5-methyl-6-chlorpyrimidine, X., reacted with potassium thiocyanate, under certain conditions, to give the corresponding isothiocyanates. They did not obtain any positive evidence of the intermediate formation of thiocyanates:



(Allylchloride.)



(1,2-Dichlorpropylene.)



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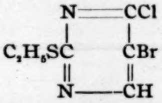

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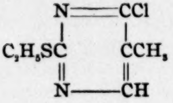
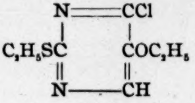


X.



XI.

We had occasion to examine, in the course of our work, the behavior of 2-ethylmercapto-5-ethoxy-6-chlorpyrimidine,[1] XI., towards potassium thiocyanate. On account of the close analogy of this imide chloride to those examined by Wheeler and Bristol,[1] we expected that it would react in a similar manner to form an isothiocyanate. We find that this chloride, XI., reacts smoothly with potassium thiocyanate, in an alcoholic solution, to give a normal rhodanide, XII., as represented in the following equation :

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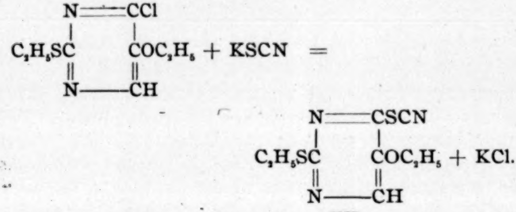
[1] Johnson and McCollum: J. Biolog. Chem., 1, 437 (1906).



XII.

That a thiocyanate is the primary product of this reaction, we have established in the following manner: It did not give thiourea derivatives with ammonia or organic bases. It reacted quantitatively with thiobenzoic and thioacetic acids to give the same 2-ethylmercapto-5-ethoxy-6-thiopyrimidine, XIV. This reaction with thioacids involves the intermediate formation of 2-ethylmercapto-5-ethoxy-6-benzoylmercaptopyrimidine, XIII., and 2-ethylmercapto-5-ethoxy-6-acetylmercaptopyrimidine,[2] XV., which then undergo hydrolysis to the thiopyrimidine, XIV.

We find that 2-ethylmercapto-5-ethoxy-6-thiocyanpyrimidine, XII., shows no tendency to rearrange to the isothiocyanate,[3] XVI., at the ordinary temperature. On the other hand, if heated above 100° it is transformed quantitatively into its isomer, XVI. The thiocyanate can be recrystallized from alcohol, but on prolonged boiling it partially rearranges to the isothiocyanate. This combines at once with the alcohol to form a urethane, XVII.

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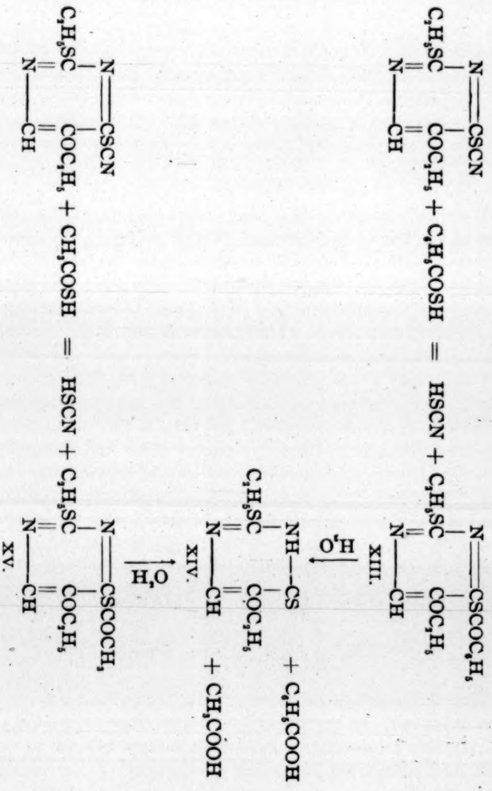
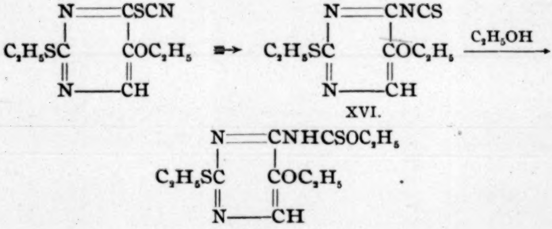
[1] *Loc. cit.*

[2] Wheeler and Merriam: THIS JOURNAL, **23**, 283 (1901).

[3] Samples of the thiocyanate that had been preserved for five months showed no change in melting point. We shall keep specimens for an indefinite period in order to see whether any rearrangement will take place at the ordinary temperature.

T. B. J.


N=CSCN
C₂H₅SC COC₂H₅
N—CH
+ C₂H₅COSH = HSCN +
N=CSCOC₂H₅
C₂H₅SC COC₂H₅
N—CH
XIII.
H₂O
NH—CS
C₂H₅SC COC₂H₅
N—CH
+ C₂H₅COOH
+ CH₃COOH
XIV.
H₂O
N=CSCN
C₂H₅SC COC₂H₅
N—CH
+ CH₃COSH = HSCN +
N=CSCOCH₃
C₂H₅SC COC₂H₅
N—CH
XV.

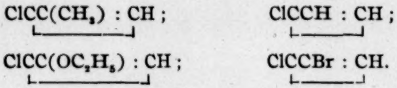


XVI.

XVII.

It seems very probable to the writers that the imide chlorides examined by Wheeler and Bristol[1] will give thiocyanates if treated with potassium thiocyanate under the proper conditions. Judging from the properties of 2-ethylmercapto-5-ethoxy-6-thiocyanpyrimidine, XII., their thiocyanates would be expected to undergo a rearrangement under the conditions employed in their experiments.

These four imide chlorides constitute an ideal series with which to test the rule as to whether the tendency for a thiocyanate to rearrange to an isothiocyanate is proportional to the negative character of the alkyl group. The only difference in structure is the character of the radicals occupying the 5-position. If the tendency to form isothiocyanates is directly proportional to the negative influence of these four radicals, evidently the negative character of the pyrimidines in question must be expressed by the following arrangement :



$ClCC(CH_3) : CH$; $ClCCH : CH$;

$ClCC(OC_2H_5) : CH$; $ClCCBr : CH$.

That the negative influence of the radicals occupying the 5-position is to be represented by the arrangement—CH_3, H, OC_2H_5, Br—is shown on substituting these groups in acetic acid and comparing the affinity constants[2] of the resulting acids.

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[1] *Loc. cit.*

[2] Ostwald: Phys. Chem., 3, 174-184.

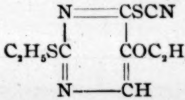
CH_3CH_2COOH, $K = 0.00134$ HCH_2COOH, $K = 0.0018$

$C_2H_5OCH_2COOH$, $K = 0.0234$ $BrCH_2COOH$. $K = 0.138$

The affinity constant in the case of acetic acid is decreased by the introduction of the methyl radical, while by the substitution of the more negative ethoxy group it is increased in the proportion 1 : 13. The investigation of these thiocyanate derivatives is now in progress in this laboratory.

EXPERIMENTAL PART.

2-Ethylmercapto-5-ethoxy-6-thiocyanpyrimidine,



—Twenty-one grams of 2-ethylmercapto-5-ethoxy-6-chlorpyrimidine[1] and 11 grams of potassium thiocyanate were dissolved in 95 per cent alcohol and the solution boiled for 6 hours. Potassium chloride began to separate immediately on warming and by prolonged boiling the alcoholic solution assumed a red color. After the completion of the reaction the excess of alcohol was removed by evaporation and the residue treated with cold water, to extract the potassium chloride and the excess of potassium thiocyanate. We obtained a well crystallized product that was soluble in hot alcohol and benzene. It deposited from alcohol in lemon-yellow prisms, which melted, at 66°–67°, to a clear oil. When heated above its melting point it showed no signs of decomposition below 200°. It was insoluble in alkali and was not changed when warmed with aqueous ammonia. It possessed the properties of a weak base. It dissolved in strong hydrochloric acid and was reprecipitated unaltered by alkali or by dilution with water. Analysis (Kjeldahl) :

	Calculated for $C_9H_{11}ON_3S_2$.	Found.
N	17.42	17.12

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[1] Johnson and McCollum : J. Biolog. Chem., 1, 443 (1906).

Action of Thiobenzoic Acid and Thioacetic Acid on 2-Ethylmercapto-5-ethoxy-6-thiocyanpyrimidine.

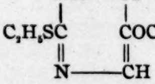
Two and five-tenths grams of the thiocyanate were dissolved in one molecular proportion of thiobenzoic acid. The substances reacted at once with the evolution of considerable heat. After warming for a few minutes in a boiling water-bath, to complete the reaction, the product was treated with a little alcohol, when it crystallized in the form of well developed, yellow prisms. It was purified for analysis by crystallization from alcohol. It melted, at 144°–145°, to a clear oil. Nitrogen determinations agreed with the calculated value in *2-ethylmercapto-5-ethoxy-6-thiopyrimidine* (see below) :

	Calculated for $C_8H_{12}ON_2S_2$.	Found. I.	II.	III.
N	12.96	13.2	12.88	13.2

Two grams of the thiocyanate were dissolved, at the ordinary temperature, in 1 molecular proportion of thioacetic acid. After a few minutes heat began to be evolved and the mixture solidified. It was then warmed in a boiling water-bath for a few minutes. The product crystallized from 95 per cent alcohol in yellow prisms and melted, at 144°–145°, to a clear oil. When this material was mixed with some of the compound obtained by the action of thiobenzoic acid on the thiocyanate, and heated in a capillary tube, the melting point was not lowered. The two substances were identical. We did not detect the formation of any carbon bisulphide in these reactions with thioacids.[1] When the mother liquors were treated with a solution of ferric chloride we obtained characteristic, red colored solutions, showing the presence of free thiocyanic acid. Analysis (Kjeldahl) :

	Calculated for $C_8H_{12}ON_2S_2$.	Found.
N	12.96	13.2

2-Ethylmercapto-5-ethoxy-6-thiopyrimidine,



—For the purpose of identification this

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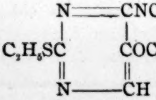
[1] Wheeler and Merriam : J. Am. Chem. Soc., 23, 284.

compound was prepared by boiling 2-ethylmercapto-5-ethoxy-6-chlorpyrimidine with an alcoholic solution of potassium hydrosulphide. The reaction was smooth and potassium chloride precipitated at once from the alcohol. When the solution was acidified with acetic acid the pyrimidine separated as a yellow, crystalline substance. It deposited from alcohol in prisms and melted, at 144°–145°, to a clear oil. When this material was mixed with the compounds obtained in the reactions with thioacids, described above, the melting point was not changed. Analysis:

	Calculated for $C_8H_{12}ON_2S_2$.	Found.
N	12.96	13.2

2-Ethylmercapto-5-ethoxy-6-isothiocyanpyrimidine,



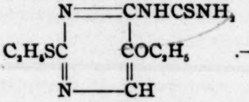
.—2-Ethylmercapto-5-ethoxy-6-thiocyanpyrimidine shows no tendency to rearrange into the isothiocyanate at ordinary temperatures. In order to decide at what temperature this rearrangement would take place we performed the following experiments: One gram of the thiocyanate was heated in a sulphuric acid-bath, at 80°–90°, for 1 hour. On cooling, the material crystallized immediately. It melted, at 66°–67°, to a clear oil and was identified as the unaltered thiocyanate. It was then heated for another hour at 90°–100°. The material solidified on cooling and melted sharply at 66°–67°. It was then heated for 3 hours at 105°–110°. On cooling the material refused to solidify and, after standing for several days, still retained the consistency of a syrup. That this product was an isothiocyanate was proved as follows: It reacted at once with ammonia to give practically a quantitative yield of 2-ethylmercapto-5-ethoxy-6-thioureapyrimidine (see below) which melted, at 171°–172°, to a clear oil.

In order to obtain the isothiocyanate sufficiently pure for analysis, 10 grams of the thiocyanate were distilled under diminished pressure. Much decomposition took place, but we obtained a fraction boiling at 228°–235° (20–23 mm.). This oil was exceedingly hygroscopic and weighed 5 grams. When allowed to stand in a desiccator, over concentrated sulphuric acid, it finally solidified. It was exceedingly soluble in the common organic solvents and, when exposed to the air, began to assume an oily appearance. The crude material melted, at 45°–50°, to a turbid oil. Analysis (Kjeldahl):

	Calculated for $C_9H_{11}ON_3S_2$.	Found.
N	17.4	16.8

Two attempts were made to prepare this isothiocyanate by boiling a mixture of the chlorpyrimidine, toluene and potassium thiocyanate. In our first experiment 10 grams of the chlorpyrimidine and 5.5 grams of potassium thiocyanate were taken and the mixture boiled for 12 hours. Under these conditions we observed no evidence of any reaction. We then boiled a mixture of 5 grams of the chlorpyrimidine, 2.3 grams of potassium thiocyanate and toluene for 30 hours. On evaporating the excess of toluene and crystallizing the residue from petroleum ether, we recovered 4 grams of the unaltered chloride melting at 44°.

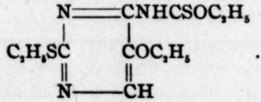
2-Ethylmercapto-5-ethoxy-6-thioureapyrimidine,



.—This thiourea was formed readily when the isothiocyanate above described was treated with aqueous ammonia. It deposited from hot alcohol in slender, yellow prisms, that melted at 172°, without effervescence, to a clear oil. Analysis (Kjeldahl):

	Calculated for $C_9H_{14}ON_4S_2$.	Found.
N	21.70	21.47

2-Ethylmercapto-5-ethoxy-6-thionethylurethanepyrimidine,



.—2-Ethylmercapto-5-ethoxy-6-

thiocyanpyrimidine undergoes a rearrangement into the isomeric isothiocyanate derivative when boiled with alcohol. Thirty-five grams of 2-ethylmercapto-5-ethoxy-6-chlorpyrimidine and 20 grams of potassium thiocyanate were dissolved in 95 per cent alcohol and the solution boiled for 11 hours. When we evaporated the alcohol and treated the residue with cold water, to remove potassium chloride and potassium thiocyanate, we obtained a semi-solid which showed no signs of crystallizing after standing for 3 hours. This material was then treated with a dilute solution of sodium hydroxide. We observed that part of the substance dissolved in the alkali and the insoluble portion assumed a crystalline form. This was filtered off and recrystallized from alcohol. It deposited in prisms that melted at 66°–67°. It was identified as the thiocyanate. Analysis (Kjeldahl):

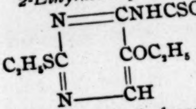
	Calculated for $C_9H_{11}ON_3S_2$.	Found.
N	17.42	17.16

The urethane that was dissolved by the alkali was recovered when we acidified the solution with hydrochloric acid. It separated in light yellow prisms. It was insoluble in hot and cold water and very soluble in hot alcohol. It deposited from alcohol in long prisms, which showed signs of melting at 89° and then melted at 93°–94°, to an oil. The yields of thiocyanate and urethane were about equal. Analysis (Kjeldahl):

	Calculated for $C_{11}H_{17}O_2N_3S_2$.	Found.
N	14.63	14.85

In order to study the velocity of the rearrangement of the thiocyanate into its isomer in boiling ethyl alcohol, we performed the following experiments: Fifteen grams of 2-ethylmercapto-5-ethoxy-6-chlorpyrimidine and 9 grams of potassium thiocyanate were boiled in alcohol for 24 hours. After separating the urethane from the thiocyanate in the usual way and then recrystallizing the compounds from alcohol, we obtained 1.2 grams of the thiocyanate and 10 grams of the urethane. In a second experiment we used 15 grams of the chlorpyrimidine, 9 grams of potassium thiocyanate and boiled the alcoholic solution 4 hours. We obtained 10 grams of thiocyanate or 60.6 per cent of the theoretical, and 1.3 grams of urethane. In no case did our combined yields of thiocyanate and urethane correspond to more than 60–70 per cent of the theoretical. In order to demonstrate that this loss is due to the fact that the urethane slowly volatilizes when the alcoholic solutions are evaporated, we performed the following experiment: An alcoholic solution of 15 grams of the imide chloride and 6.6 grams of potassium thiocyanate was boiled for 30 hours. The alcoholic solution was then treated with a molecular proportion of sodium ethylate, to form a sodium salt of the urethane and evaporated to dryness. We obtained 4.9 grams of thiocyanate. The urethane was obtained by neutralizing its sodium salt with acetic acid and weighed 9.85 grams. These yields accounted for 95.26 per cent of the imide chloride used in the experiment.

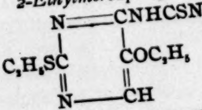
2-Ethylmercapto-5-ethoxy-6-thionpropylurethanepyrimidine,



.—This urethane was formed when 3 grams of 2-ethylmercapto-5-ethoxy-6-chlorpyrimidine and 2 grams of potassium thiocyanate were dissolved in normal propyl alcohol and the solution boiled for 6 hours. Under these conditions we did not obtain any thiocyanate. The urethane was purified by recrystallizing from 95 per cent alcohol. It deposited in small prisms that melted, at 56°–57°, without effervescence, to a clear oil. Analysis (Kjeldahl):

	Calculated for $C_{12}H_{19}O_2N_3S_2$.	Found.
N	13.95	13.76

2-Ethylmercapto-5-ethoxy-6-phenylthioureapyrimidine,

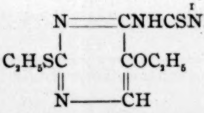


.—The common method of procedure in the preparation of the thioureas described in this paper was to heat the 2-ethylmercapto-5-ethoxy-6-thiocyanpyrimidine in an oil-bath at 150°–160°, for about 30 minutes and thoroughly rearrange it to the isothiocyanate. This was then dissolved in a little benzene and combined with a molecular proportion of the organic base. The reactions were usually accompanied with evolution of heat and the yields of thioureas were practically quantitative.

The phenylthiourea derivative was soluble in hot alcohol and insoluble in water. It deposited from alcohol in distorted prisms and melted, at 82°–83°, to a clear oil. Analysis (Kjeldahl):

	Calculated for $C_{15}H_{18}ON_4S_2$.	Found.
N	16.76	16.75

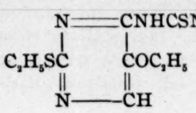
2-Ethylmercapto-5-ethoxy-6-paratolylthioureapyrimidine,



.—This thiourea was insoluble in water. It was soluble in hot alcohol but insoluble in cold. It deposited from alcohol in clusters of needles radiating from a common center. They melted, at 115°, to a clear oil, without effervescence. Analysis (Kjeldahl):

	Calculated for $C_{16}H_{20}ON_4S_2$.	Found.
N	16.09	16.20

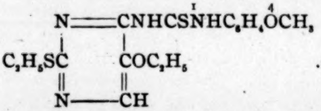
2-Ethylmercapto-5-ethoxy-6-orthotolylthioureapyrimidine,



.—This thiourea was insoluble in water and soluble in warm alcohol. It deposited from alcohol in rhombic-shaped prisms and melted, at 129°–130°, to a clear oil.

	Calculated for $C_{16}H_{20}ON_4S_2$.	Found.
N	16.09	15.86

2-Ethylmercapto-5-ethoxy-6-paraanisylthioureapyrimidine,

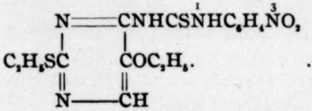


$$\begin{array}{lll} \mathrm{N} & = & \mathrm{CNHCS\overset{1}{N}HC_6H_4\overset{4}{O}CH_3} \\ | & & | \\ \mathrm{C_2H_5SC} & & \mathrm{COC_2H_5} \\ \| & & \| \\ \mathrm{N} & - & \mathrm{CH} \end{array}$$

.—From paraanisidine and 2-ethylmercapto-5-ethoxy-6-isothiocyanpyrimidine. This base showed little tendency to react with the isothiocyanate at ordinary temperatures. In order to complete the action the mixture was heated in a boiling water-bath, for 6 hours. The product was then washed with dilute hydrochloric acid to remove unaltered anisidine and afterwards purified by crystallizing from 95 per cent alcohol. It deposited from alcohol in rhombic prisms and melted at 122°–123°. Analysis (Kjeldahl):

	Calculated for $C_{16}H_{20}O_2N_4S_2$.	Found.
N	15.38	15.53

2-Ethylmercapto-5-ethoxy-6-metanitrophenylthioureapyrimidine,



$$\begin{array}{lll} \mathrm{N} & = & \mathrm{CNHCS\overset{1}{N}HC_6H_4\overset{3}{N}O_2} \\ | & & | \\ \mathrm{C_2H_5SC} & & \mathrm{COC_2H_5.} \\ \| & & \| \\ \mathrm{N} & - & \mathrm{CH} \end{array}$$

.—This thiourea was obtained when 1 gram of 2-ethylmercapto-5-ethoxy-6-isothiocyanate and a molecular proportion of metanitraniline were dissolved in benzene and digested on the steam-bath, for 1 hour. When the benzene was evaporated the thiourea remained as an oil, which soon solidified. It was insoluble in hot water and slightly soluble in alcohol. It crystallized from benzene in the form of slender prisms which melted, at 161°, without effervescence, to a clear oil. Analysis (Kjeldahl):

	Calculated for $C_{15}H_{17}O_3N_5S_2$.	Found. I.	II.	III.	IV.
N	18.47	18.23	18.23	18.09	18.10

NEW HAVEN, CONN.,
May 5, 1906.

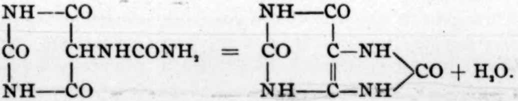
Contributions from the Sheffield Laboratory of Yale University.

CXXXII.—RESEARCHES ON PYRIMIDINES: ON THE FORMATION OF PURINES FROM UREA-PYRIMIDINES.

[SIXTEENTH PAPER.]

BY TREAT B. JOHNSON AND ELMER V. McCOLLUM.

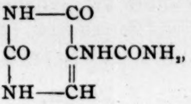
It has been shown by several investigators[1] that 5-ureapyrimidines, in which the 4 and 6 positions are occupied by oxygen, I., condense to purines when heated with oxalic or hydrochloric acids. The condensation of 2,4,6-trioxy-5-ureapyrimidine (pseudouric acid), I., to uric acid,[2] II., represents the simplest case of this method of purine formation.



$$\begin{array}{lll} NH & — & CO \\ | & & | \\ CO & & CHNHCONH_2 \\ | & & | \\ NH & — & CO \end{array} = \begin{array}{lll} NH & — & CO \\ | & & | \\ CO & & C{-}NH \\ | & & \| \\ NH & — & C{-}NH \end{array}\!\!\!>CO + H_2O.$$

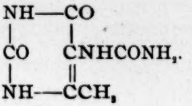
I. II.

On the other hand, 5-ureapyrimidines, III., IV., in which hydrogen or an alkyl radical occupies the 4-position, show no tendency to undergo a similar condensation when treated with dehydrating agents. Behrend[3] obtained no evidence of the formation of purines when 2,6-dioxy-5-ureapyrimidine (hydroxyxanthine), III., and 2,6-dioxy-4-methyl-5-ureapyrimidine (methylhydroxyxanthine), IV., were treated, under various conditions, with phosphorus pentachloride, sulphuric acid, acetic anhydride and chlorsulphonic acid.



$$\begin{array}{lll} NH & — & CO \\ | & & | \\ CO & & CNHCONH_2, \\ | & & \| \\ NH & — & CH \end{array}$$

III.



$$\begin{array}{lll} NH & — & CO \\ | & & | \\ CO & & CNHCONH_2. \\ | & & \| \\ NH & — & CCH_3 \end{array}$$

IV.

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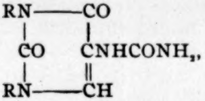
[1] Fischer and Ach: Ber. d. chem. Ges., **28**, 2473. Fischer: *Ibid.*, **30**, 559; **33**, 1701. Sembritski: *Ibid.*, **30**, 1814. Armstrong: *Ibid.*, **33**, 2308.

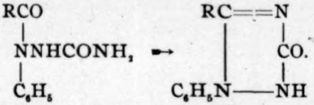
[2] Fischer and Ach: *Loc. cit.*

[3] Ann. Chem. (Liebig), **229**, 40; **231**, 248, 251; **240**, 1.

This observation of Behrend's was later confirmed by Widman.[1] He investigated the behavior of 2,6-dioxy-5-ureapyrimidines, V., towards potassium hydroxide. On account of the structural relationship between such ureapyrimidines and acylsemicarbazides, VI., it was important to compare their behavior towards this reagent. He found that the ureapyrimidines, V., could be recovered unaltered after warming with dilute solutions of potassium hydroxide, while the acylsemicarbazides, VI., condensed smoothly to triazoles,[2] VII.

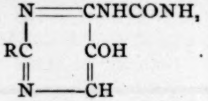


V.



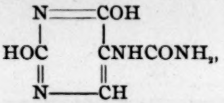
VI. VII.

On account of the pronounced difference in behavior of 4,6-dioxy-5-ureapyrimidines from 6-oxy-5-ureapyrimidines, III. and IV., it seemed desirable to prepare a 5-hydroxy-6-ureapyrimidine, VIII. It was of interest to decide whether such a ureapyrimidine derivative would undergo an inner condensation to form a purine.

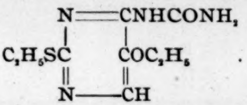


VIII.

We have selected as a suitable representative of this new class of hydroxyureapyrimidines 2-ethylmercapto-5-ethoxy-6-ureapyrimidine, X. The structural relationship between this pyrimidine and Behrend's hydroxyxanthine, III., is illustrated by representing the oxygen derivative in its *enol* form, IX.:



IX.



X.

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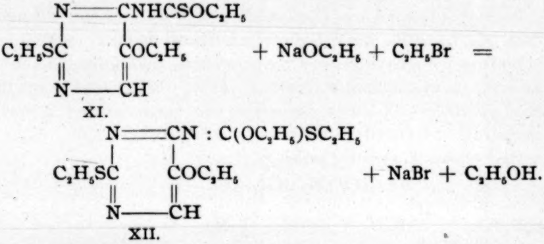
[1] Ber. d. chem. Ges., **29**, 1954 (1896).

[2] Widman: Ber. d. chem. Ges., **29**, 1946.

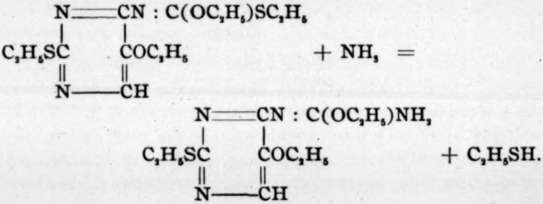
We have prepared this urea derivative, X., in the following manner: When 2-ethylmercapto-5-ethoxy-6-thionethylurethanepyrimidine,[1] XI., was treated with molecular proportions of sodium ethylate and ethyl bromide, it gave 2-ethylmercapto-5-ethoxy-6-iminothioethylcarbonatepyrimidine, XII.:



XI.

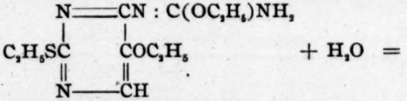
XII.

This iminothiocarbonate, XII., evolved ethylmercaptan when treated with alcoholic ammonia and was converted, practically quantitatively, into 2-ethylmercapto-5-ethoxy-6-pseudoethylureapyrimidine, XIII.:



XIII.

This pseudourea, XIII., then gave the normal urea, X., when treated with cold, concentrated hydrochloric acid:



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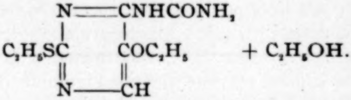
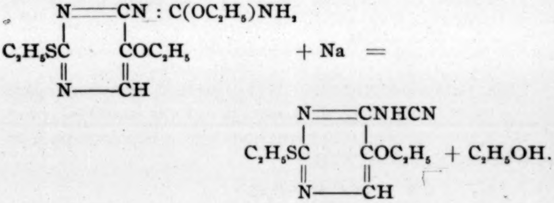
[1] Johnson and McCollum: THIS JOURNAL, **36**, 136 (1906).



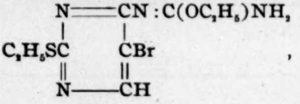
X.

Attempts to condense the pseudourea, XIII., or the normal urea, X., to purine derivatives were without success. Sodium, in boiling benzene, attacked the pseudoureapyrimidine, XIII., to form a cyanaminopyrimidine, XIV. When the normal ureapyrimidine, X., was treated in the same manner it was recovered unaltered. It underwent decomposition when heated above its melting point:

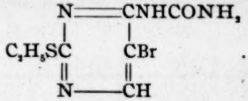


XIV.

The 5-ethoxy radical in the above ureapyrimidines, XIII., and X., apparently is as firmly linked as the bromine atoms in the 5-brom-6-ureapyrimidines that were examined by Wheeler and Bristol.[1] They were unable to condense 2-ethylmercapto-5-brom-6-pseudoethylureapyrimidine, XV., or 2-ethylmercapto-5-brom-6-ureapyrimidine, XVI., to purine derivatives. The bromine atom in these compounds could not be removed by heating with pyridine, or by digesting in benzene with metallic sodium:



XV.



XVI.

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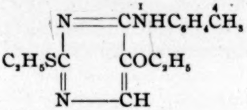
[1] This Journal, 33, 448 (1905).

In this paper we also describe a series of substituted 6-aminopyrimidines that we have prepared by warming 2-ethylmercapto-5-ethoxy-6-chlorpyrimidine[1] with organic bases. These derivatives are characterized by their stability towards boiling acids. 2-Ethylmercapto-5-ethoxy-6-paratoluidinopyrimidine, XVII., could be boiled with concentrated hydrochloric acid without removing the mercapto radical.



XVII.

EXPERIMENTAL.

Diethylformylglycollate, $C_2H_5OCH(CHO)COOC_2H_5$. — The sodium salt of this ester was described in a previous paper by Johnson and McCollum.[2] We now find that the free ester can easily be prepared from this sodium salt. It separated as a colorless oil when an aqueous solution of the sodium salt was acidified with hydrochloric acid. It was purified by fractional distillation, under diminished pressure. A fraction that distilled at 115°-118° (35 mm.) was used for the analytical determinations.

I. 0.4711 gram substance gave 0.8763 gram CO_2 and 0.3190 gram H_2O.

II. 0.4732 gram substance gave 0.8853 gram CO_2 and 0.3176 gram H_2O.

III. 0.4677 gram substance gave 0.8762 gram CO_2 and 0.3121 gram H_2O.

	Calculated for $C_7H_{12}O_4$.	Found. I.	II.	III.
C	52.5	50.72	51.02	51.09
H	7.5	7.33	7.45	7.41

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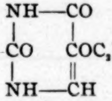
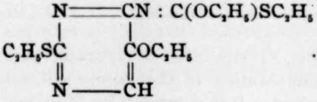
[1] Johnson and McCollum: *Loc. cit.*

[2] J. Biolog. Chem., 1, 437.

2,6-Dioxy-5-ethoxypyrimidine,  — This compound was described in a previous publication by Johnson and McCollum.[1] It was obtained, associated with isobarbituric acid, when 2-ethylmercapto-5-ethoxypyrimidine was heated in a sealed tube, with hydrochloric acid. We find that this pyrimidine can easily be prepared by boiling 2-methylmercapto-5-ethoxypyrimidine[2] with hydrochloric acid. It agreed in its properties with the compound described in our former paper. Analysis (Kjeldahl):

	Calculated for $C_6H_8O_3N_2$.	Found.
N	17.95	18.00

2-Ethylmercapto-5-ethoxy-6-iminothioethylcarbonatepyrimidine,  .—Twelve grams of 2-ethylmercapto-5-ethoxy-6-thionethylurethanepyrimidine[2] were dissolved in alcohol containing one molecular proportion of metallic sodium. Four and five-tenths grams of ethyl bromide were then added and the solution allowed to stand at the ordinary temperature until neutral to litmus. After the reaction was complete the excess of alcohol was evaporated on the steam-bath, and the oily residue treated with cold water to remove sodium bromide. An oil was obtained which was extracted with ether and dried over calcium chloride. When the ether was evaporated, the diethylcarbonate remained as an oil which would not solidify. Analysis (Kjeldahl):

	Calculated for $C_{13}H_{21}O_2N_3S_2$.	Found.
N	13.33	12.94

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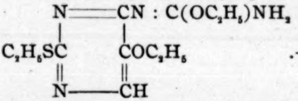
[1] *Loc. cit.*

[2] Johnson and McCollum : *Loc. cit.*

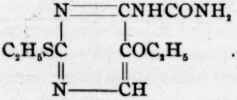
2-Ethylmercapto-5-ethoxy-6-pseudoethylureapyrimidine,



.—This derivative was obtained when dry ammonia gas was passed into an alcoholic solution of the above iminothioethylcarbonate. When the alcoholic solution was evaporated to dryness the pseudourea was obtained as a well crystallized compound. It was very soluble in alcohol and benzene and was purified for analysis by recrystallizing from ligroin. It melted, at 77°, to a clear oil. Analysis (Kjeldahl):

	Calculated for $C_{11}H_{18}O_2N_4S$.	Found.
N	20.74	20.40

2-Ethylmercapto-5-ethoxy-6-ureapyrimidine,



.—This urea was obtained when the above pseudourea was allowed to stand dissolved in concentrated hydrochloric acid. After remaining a few days, the urea was precipitated by adding water. It was readily soluble in hot alcohol and deposited from cold alcohol in prismatic crystals, which melted at 166°-167°, with slight effervescence, to a clear oil. It gave a strong test for sulphur, but did not contain chlorine. When mixed with 2-ethylmercapto-5-ethoxy-6-oxypyrimidine[1] (m. p. 166°-167°) the melting point was lowered to 140°-143°. Analysis (Kjeldahl):

	Calculated for $C_9H_{14}O_2N_4S$.	Found.
N	23.14	23.17

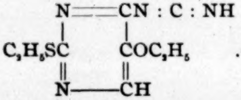
One gram of this urea and 1.5 grams of metallic sodium were suspended in benzene and the mixture boiled for 20 hours. There was no evidence of any reaction except that the sodium became coated with a thin deposit. When the benzene was evaporated and the sodium dissolved in alcohol, we obtained a crystalline deposit that melted at about 166°. It crystallized from hot, 95 per cent alcohol in prisms that melted at 166°–167°, with slight effervescence. It was identified as the unaltered urea. We did not observe the formation of the cyanaminopyrimidine (see below). Analysis (Kjeldahl):

---

[1] Johnson and McCollum: *Loc. cit.*

	Calculated for $C_9H_{14}O_2N_4S$.	Found.
N	23.14	23.07

2-Ethylmercapto-5-ethoxy-6-cyanaminopyrimidine,

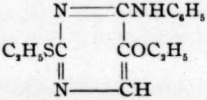


.—About 1 gram of 2-ethylmercapto-5-ethoxy-6-pseudoethylureapyrimidine was dissolved in dry benzene and treated with a slight excess over one molecular proportion of metallic sodium. The mixture was then boiled for 40 hours. The sodium underwent a complete change by this treatment and was transformed into a slimy precipitate. On filtering and evaporating the benzene there was no residue. The precipitate that remained on the filter was dissolved in alcohol and the solution evaporated to dryness. The residue was then dissolved in cold water. When this solution was acidified with acetic acid a white, crystalline product separated in the form of prisms. The substance melted sharply at 167°–168°, with only slight effervescence. It was soluble in alkali and was reprecipitated by acids. It was insoluble in cold, but readily soluble in hot water and alcohol. When dissolved in boiling water it slowly decomposed. On cooling it deposited in prismatic crystals that melted at about 165°–166°. When the cyanamide derivative (m. p. 167°–168°) was mixed with the above urea (m. p. 166°–167°) the melting point was lowered to 148°–155°. Analysis (Kjeldahl):

	Calculated for $C_9H_{12}ON_4S$.	Found.
N	25.00	24.95

About 0.5 gram of the cyanamide derivative was allowed to stand dissolved in a few cc. of concentrated hydrochloric acid. A deposit of slender prisms was obtained which gave a strong test for chlorine. They melted at 175°–180°, with violent effervescence, and had all the properties of a hydrochloric acid salt. On treating with dilute ammonia they completely dissolved, but on standing the solution deposited prismatic crystals that melted at 166°–167°. This was identified as 2-ethylmercapto-5-ethoxy-6-ureapyrimidine. When it was mixed with this urea the melting point was not lowered.

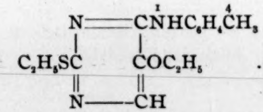
2-Ethylmercapto-5-ethoxy-6-anilinopyrimidine,



.—This base was obtained when an alcoholic solution of 3 grams of 2-ethylmercapto-5-ethoxy-6-chlorpyrimidine and 2.8 grams of aniline were boiled for 24 hours. It was insoluble in water and very soluble in alcohol. It deposited from ligroin in large prisms, which melted at 60°. Analysis (Kjeldahl):

	Calculated for $C_{14}H_{17}ON_3S$.	Found.
N	15.27	15.19

2-Ethylmercapto-5-ethoxy-6-paratoluidinopyrimidine,



.—This base was obtained as an oil when an alcoholic solution of 2-ethylmercapto-5-ethoxy-6-chlorpyrimidine and the calculated quantity of paratoluidine was boiled for 10 hours. It formed a well crystallized hydrochloride, that deposited from water in hair-like crystals and melted at 105°–106°, with effervescence. Analysis (Kjeldahl):

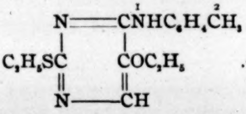
	Calculated for $C_{15}H_{19}ON_3S.HCl$.	Found.
N	12.90	12.71

When the hydrochloride was treated with dilute ammonia the free base precipitated as an oil. It was soluble in ether and ligroin. It deposited from ligroin in long prisms, that melted at 72°. Analysis (Kjeldahl):

	Calculated for $C_{15}H_{19}ON_3S$.	Found.
N	14.53	14.57

This mercaptopyrimidine can be boiled with concentrated hydrochloric acid without decomposition. After boiling 0.7 gram with an excess of hydrochloric acid, for 12 hours, it was recovered unaltered and melted sharply at 72°.

2-Ethylmercapto-5-ethoxy-6-orthotoluidinopyrimidine,



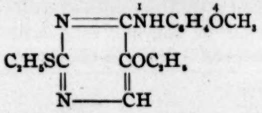
.—From orthotoluidine and 2-ethylmercapto-5-ethoxy-6-chlorpyrimidine. Its hydrochloric acid salt crystallized from alcohol in prisms, that decomposed at 140°-145°. The salt is not stable in aqueous solution and dissociates into the base and hydrochloric acid. Analysis (Kjeldahl):

	Calculated for $C_{15}H_{19}ON_3S.HCl$.	Found.
N	12.90	12.30

The free base is insoluble in water, and very soluble in alcohol. It deposited from alcohol in flat prisms, that melted at 80°. It was insoluble in ligroin. Analysis (Kjeldahl):

	Calculated for $C_{15}H_{19}ON_3S$.	Found.
N	14.53	14.49

2-Ethylmercapto-5-ethoxy-6-paraanisidinopyrimidine,



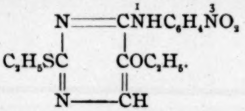
. — From paraanisidine and 2-ethylmercapto-5-ethoxy-6-chlorpyrimidine. This reaction was not as smooth as those with the preceding amines. The base was first obtained as an oil which would not solidify. It was dissolved in dry benzene and the solution saturated with dry hydrochloric acid gas. The hydrochloride deposited in prismatic crystals. It was purified by recrystallization from acetone or ethyl acetate and was insoluble in benzene and ligroin. Analysis (Kjeldahl) :

	Calculated for $C_{15}H_{19}O_2N_3S.HCl$.	Found.
N	12.29	12.19

When the hydrochloride was treated with ammonia the base was obtained as an oil which finally solidified. It deposited from alcohol in stout prisms, that melted at 68°–69°, without effervescence, to a clear oil. It was insoluble in water. Analysis (Kjeldahl) :

	Calculated for $C_{15}H_{19}O_2N_3S$.	Found.	
		I.	II.
N	13.77	13.77	13.81

2-Ethylmercapto-5-ethoxy-6-metanitroanilinopyrimidine,



.—The hydrochloride of this pyrimidine base crystallized from alcohol and melted at 125°–135°, with effervescence. The base was insoluble in water. It deposited from alcohol in long needles, which melted, at 125°, to a clear oil. Analysis (Kjeldahl) :

	Calculated for $C_{14}H_{16}O_3N_4S$.	Found.
N	17.50	17.13

NEW HAVEN, CONN.,
May 5, 1906.

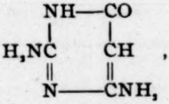
Contributions from the Sheffield Laboratory of Yale University.

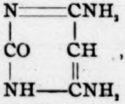
CXXXIII.—RESEARCHES ON PYRIMIDINES: ON 5-NITROCYTOSINE AND ITS REDUCTION TO 2-OXY-5,6-DIAMINOPYRIMIDINE.

[SEVENTEENTH PAPER.]

BY TREAT B. JOHNSON, CARL O. JOHNS AND FREDERICK W. HEYL.

There are five possible monooxydiaminopyrimidines in which the oxygen atom can occupy positions 2 and 6, assuming that the amino groups are attached to carbon. Their formulae are given below, I.–V. Three of these have been synthesized, *viz.*: 2,4-diamino-6-oxypyrimidine,[1] I., 2-oxy-4,6-diaminopyrimidine,[2] II., and 6-oxy-2,5-diaminopyrimidine,[3] III. In this paper we shall describe the fourth member of this series —2-oxy-5,6-diaminopyrimidine, IV.:


I.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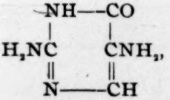
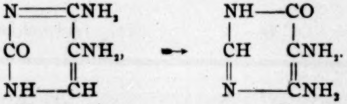

III.


IV. V.

In a previous paper from this laboratory, Wheeler and Johnson[4] have shown that cytosine is converted into nitrocytosine when treated with a mixture of nitric and sulphuric acids. No attempt was made to establish the structure of this nitro derivative. They assumed, nevertheless, on account of the unstable character of the products formed on reduction, that they were dealing with a nitramine, VI., instead of 5-nitrocytosine, VII.:

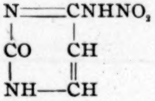
---

[1] Traube: Ber. d chem. Ges., 33, 1371.

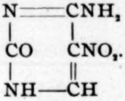
[2] Wheeler and Jamieson: THIS JOURNAL, 32, 342 (1904).

[3] Johnson and Johns: *Ibid.*, 34, 554 (1905).

[4] *Ibid.*, 31, 591 (1904).



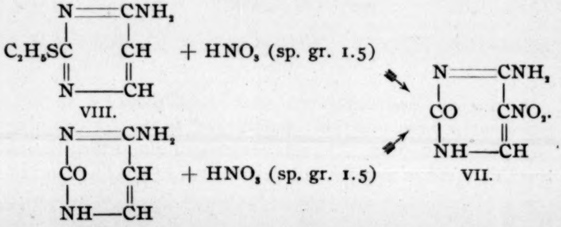
VI.



VII.

In the course of our work on oxydiaminopyrimidines it was necessary to decide whether the structure of nitrocytosine is to be represented by Formula, VI., or by Formula VII. If it is a 5-nitropyrimidine, VII., it seemed probable that it might give a diaminopyrimidine when reduced under the proper conditions.

The nitrocytosine that was used in this research was prepared by dissolving 2-ethylmercapto-6-aminopyrimidine,[1] VIII., in a mixture of concentrated nitric and sulphuric acids. It was converted, practically quantitatively, into the same nitropyrimidine, VII., as was obtained from cytosine,[2] IX.



VIII.

IX.

VII.

We now conclude that this nitro derivative is 2-oxy-5-nitro-6-aminopyrimidine, VII., and not a nitramine, VI., as represented in the previous paper.[2] That this conclusion is correct is established by the following data:

When nitrocytosine was heated under pressure, with 20 per cent sulphuric acid, it was converted into nitrouracil, X.:

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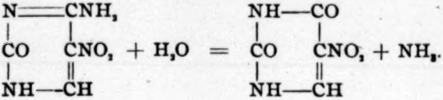
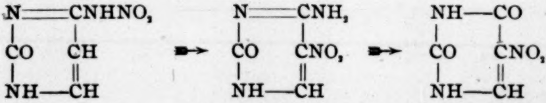
[1] Wheeler and Johnson: This Journal, 29, 497 (1903).

[2] Wheeler and Johnson: *Loc. cit.*



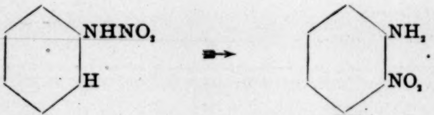
X.

This result is analogous to those obtained when cytosine and 5-methylcytosine[1] were heated with sulphuric acid. They were converted into uracil and thymine, respectively. While this result supports the assumption that the nitro group in nitrocytosine occupies the 5-position, yet there was the possibility of the nitramine, VI., giving nitrouracil under the same conditions. This would involve a rearrangement of the nitro group from the amino radical to the 5-position in the pyrimidine ring, and then a hydrolysis to nitrouracil, as represented above:



VI. VII. X.

Analogous rearrangements have been observed to take place in the benzene series. Bamberger[2] found, for example, that phenylnitramine, XI., was rearranged into orthonitroaniline, XII., when warmed with sulphuric or hydrochloric acids:



XI. XII.

Although this rearrangement is theoretically possible, yet it did not seem probable to the writers because nitrocytosine is prepared under conditions that are not favorable for the formation of a nitramine. Furthermore, we have obtained experimental evidence which shows that this rearrangement does not take place.

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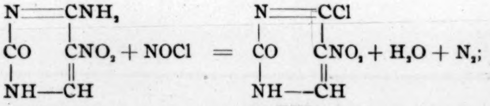
[1] Wheeler and Johnson: *Loc. cit.*

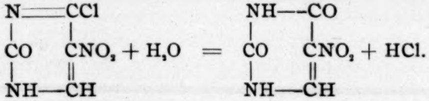
[2] Ber. d. Chem. Ges. 26, 490.

It has been observed by several investigators[1] that the amino radical in amino acids is replaced by chlorine and bromine when these acids are treated with nitrosyl chloride and nitrosyl bromide. We have investigated the behavior of nitrosyl chloride towards nitrocytosine and find that this pyrimidine is converted smoothly into nitrouracil when warmed with an aqueous solution of the reagent.[2] This reaction involves the intermediate formation of 2-oxy-5-nitro-6-chlorpyrimidine, XIII. Under the conditions employed in our experiment this imide chloride, XIII., would be decomposed with the production of nitrouracil and hydrochloric acid, as follows:



$$\begin{array}{lcl} \mathrm{N} & = & \mathrm{CNH_2} \\ | & & | \\ \mathrm{CO} & & \mathrm{CNO_2} \\ | & & \| \\ \mathrm{NH} & - & \mathrm{CH} \end{array} + \mathrm{NOCl} = \begin{array}{lcl} \mathrm{N} & = & \mathrm{CCl} \\ | & & | \\ \mathrm{CO} & & \mathrm{CNO_2} \\ | & & \| \\ \mathrm{NH} & - & \mathrm{CH} \end{array} + \mathrm{H_2O} + \mathrm{N_2};$$

XIII.



$$\begin{array}{lcl} \mathrm{N} & = & \mathrm{CCl} \\ | & & | \\ \mathrm{CO} & & \mathrm{CNO_2} \\ | & & \| \\ \mathrm{NH} & - & \mathrm{CH} \end{array} + \mathrm{H_2O} = \begin{array}{lcl} \mathrm{NH} & - & \mathrm{CO} \\ | & & | \\ \mathrm{CO} & & \mathrm{CNO_2} \\ | & & \| \\ \mathrm{NH} & - & \mathrm{CH} \end{array} + \mathrm{HCl}.$$

It appears to the writers that this method of formation of nitrouracil from nitrocytosine excludes the possibility of a rearrangement of the nitro group. The conditions of the reaction are far less favorable for a rearrangement than those employed in the preparation of nitrocytosine from 2-ethylmercapto-6-aminopyrimidine.

Furthermore, the following result would seem to indicate that there is no tendency for 2-mercapto-6-aminopyrimidines to form nitramines even when it is impossible for a nitro group to enter the 5-position in the pyrimidine ring. When 2-ethylmercapto-5-brom-6-aminopyrimidine,[1] XIV., was dissolved in a mixture of nitric and sulphuric acids it was converted, smoothly, into 5-bromcytosine,[2] XV. We obtained no evidence of the formation of a nitramine, XVI.

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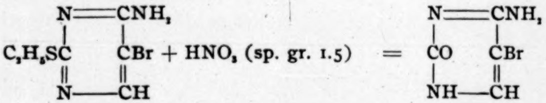
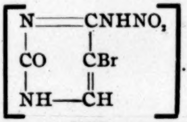
[1] Tilden and Forster: J. Chem. Soc., 67, 489. Tilden and Marshall: *Ibid.*, 67, 494. Walden: Ber. d. chem. Ges., 29, 134. Fischer: Ann. Chem. (Liebig), 340, 171. Stanek: Z. physiol. Chem., 46, 263 (1905).

[2] Stanek: *Loc. cit.*



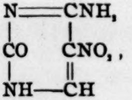
XIV.

XV.

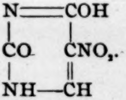


XVI.

It has been the usual experience, when a pyrimidine having a hydrogen atom in the 5-position is attacked by bromine, that this hydrogen is easily replaced by the halogen.[3] We now find that bromine has no action on nitrocytosine. This result is in accord with previous observations and again indicates that the nitro group occupies the 5-position in this pyrimidine. Behrend[4] observed that nitrouracil was recovered unaltered after heating with liquid bromine, at 100° :



(Nitrocytosine.)



(Nitrouracil.)

The above data and the facts that nitrocytosine does not give "Liebermann's reaction,"[1] or Thiele and Lachman's[2] "nitramine reaction," prove that nitrocytosine is a 2-oxy-5-nitro-6-aminopyrimidine, as represented by Formula VII.

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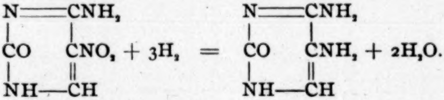
[1] Wheeler and Johnson: THIS JOURNAL, **31**, 604.

[2] Wheeler and Johnson: *Loc. cit.*

[3] Wheeler and Johnson: THIS JOURNAL, **29**, 504. *Ibid.*, **31**, 603. Gabriel and Colman: Ber. d. chem. Ges., **34**, 1238. Wheeler and Bristol: THIS JOURNAL, **33**, 437. Johnson and Johns: *Ibid.*, **34**, 175. J. Biolog. Chem., **1**, 305.

[4] Ann. Chem. (Liebig), **240**, 11.

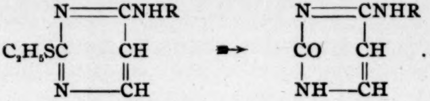
We find that 5-nitrocytosine can be reduced with aluminium-amalgam to 2-oxy-5,6-diaminopyrimidine, IV.:



IV.

The reduction was very smooth, but we encountered several experimental difficulties before we succeeded in isolating the product. The base is especially characterized by the ease with which it undergoes decomposition in aqueous solution. It is the most unstable aminopyrimidine that we have prepared in this laboratory. It gave a very insoluble picrate and was precipitated from its aqueous solution by potassiobismuth iodide, mercuric chloride and phosphotungstic acid. Like 2,5-diamino-6-oxypyrimidine,[3] it contained 1 molecule of water of crystallization.

In this paper we also describe a series of substituted 2-ethylmercapto-6-aminopyrimidines, XVII., that we have prepared by heating 2-ethylmercapto-6-chlorpyrimidine[4] with aromatic bases. These mercaptopyrimidines were converted into cytosine derivatives, XVIII., when boiled with mineral acids:



XVII. XVIII.

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[1] Ber. d. chem. Ges., 7, 248. Baeyer: *Ibid.*, 7, 966. Mahla and Tiemann: *Ibid.*, 29, 2810. Francesconi and Angelucci: Gazz. chim. ital., 31, II., 302 (1901). Scholl: Ann. Chem. (Liebig), 338, 3 (1904).

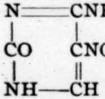
[2] Ann. Chem. (Liebig), 288, 269 (1895).

[3] Johnson and Johns: *Loc. cit.*

[4] Wheeler and Johnson: *Loc. cit.*

EXPERIMENTAL PART.

2-Oxy-5-nitro-6-aminopyrimidine (*5-Nitrocytosine*),



.—This compound has been described in a previous paper.[1] It was obtained by nitrating cytosine in the presence of sulphuric acid. We find that it can be obtained very easily by nitrating 2-ethylmercapto-6-aminopyrimidine.[2] The largest yield of nitrocytosine was obtained when we proceeded under the following conditions: Nineteen cc. of concentrated sulphuric acid were mixed with 37 cc. of nitric acid (sp. gr. 1.5). To this mixture were then slowly added 12.5 grams of the mercaptopyrimidine. The reaction was very violent and the pyrimidine dissolved immediately with evolution of much heat. After all the pyrimidine had been added the solution was allowed to stand at the ordinary temperature for about 15-16 hours. The mixture was then poured upon crushed ice and the acids neutralized with concentrated ammonia. The nitropyrimidine deposited from the neutral solution as a white, microscopic powder. It was purified by recrystallization from hot water. We obtained 10.5 grams of the nitropyrimidine, corresponding to 83.5 per cent of the theoretical yield. Analysis (Kjeldahl):

	Calculated for $C_4H_4O_3N_4$.	Found.
N	35.89	35.72

The Hydrochloride of 5-Nitrocytosine.—Nitrocytosine was dissolved in warm, dilute hydrochloric acid. Upon cooling, the hydrochloride deposited in clusters of needle-like prisms. They did not decompose below 300°. Analysis (Kjeldahl):

	Calculated for $C_4H_4O_3N_4.HCl$.	Found.
N	29.09	29.2

Behavior of 5-Nitrocytosine when Heated with Sulphuric Acid under Pressure.—Two grams of 5-nitrocytosine were heated in a sealed tube, with 20 per cent sulphuric acid, for 3 hours, at 185°–197°. When the tube was examined there was no pressure and slender prisms had deposited in the acid solution. They decomposed, with effervescence, at about 275°–277°. The compound was insoluble in acids and soluble in ammonia and in sodium hydroxide. It gave no test for sulphuric acid when warmed with a solution of barium chloride, and agreed in its behavior with that of nitrouracil. In order to demonstrate that it was nitrouracil the material was reduced in an ammoniacal solution with aluminium amalgam. After filtering from aluminium hydroxide and concentrating the filtrate to a small volume, aminouracil deposited in needles. When a solution of the base was treated with picric acid we obtained the characteristic picrate of aminouracil. It sintered at 147° and then melted at 247°, with effervescence. Analysis of the free base:

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[1] Wheeler and Johnson: *Loc. cit.*

[2] Wheeler and Merriam: *Loc. cit.*

	Calculated for $C_4H_5O_2N_3$.	Found.
N	33.06	32.9

Behavior of 5-Nitrocytosine when Heated with a Hydrochloric Acid Solution of Nitrosyl Chloride.—A solution of nitrosyl chloride was prepared according to the directions given by Stanek.[1] Three grams of nitrocytosine were heated in a sealed tube, with 40 cc. of the nitrosyl chloride solution, for 4 hours, at 85°–95°. It was then allowed to stand at the ordinary temperature for 3 days. A clear solution resulted, which slowly evolved nitrogen. When the tube was opened there was considerable pressure and a crystalline precipitate was suspended in the solution. This was difficultly soluble in hot water. It deposited, on cooling, in clusters of radiating prisms. They had no definite melting point but decomposed, without melting, when heated above 250°. It was insoluble in acids, soluble in alkalies and did not respond to a test for chlorine. A nitrogen determination agreed with the calculated value in nitrouracil (Kjeldahl):

	Calculated for $C_4H_3O_4N_3$.	Found.
N	26.75	27.00

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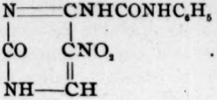
[1] Z. physiol. Chem., **46**, 265.

Action of Nitric Acid on 2-Ethylmercapto-5-brom-6-aminopyrimidine.—This mercaptobrompyrimidine[1] was nitrated under practically the same conditions as were employed in the preparation of 5-nitrocytosine from 2-ethylmercapto-6-aminopyrimidine. Eight cc. of nitric acid (sp. gr. 1.5) were mixed with 4 cc. of concentrated sulphuric acid. Two and five-tenths grams of the mercaptopyrimidine were then slowly added to this acid mixture. Much heat was evolved and the mercaptopyrimidine dissolved at once, but the reaction was not as violent as in the nitration of 2-ethylmercapto-6-aminopyrimidine. After standing for 12 hours the solution was poured upon crushed ice and the acids neutralized with ammonia. When the liquid was concentrated to a volume of 25 cc. and cooled, a microscopic powder deposited. The material was purified by crystallization from hot water. It decomposed, without melting, when heated above 230°. It contained bromine but did not respond to a test for sulphur. A nitrogen determination agreed with the calculated value in *5-bromcytosine* (Kjeldahl):

	Calculated for $C_4H_4ON_3Br$.	Found.
N	22.10	22.17

Action of Bromine on 5-Nitrocytosine.—This pyrimidine was not attacked by bromine. It was suspended in glacial acetic acid and treated with a large excess of bromine. There was no apparent change after standing for 2 days. More bromine was then added to the acetic acid and the solution warmed in a water-bath. Under these conditions no hydrobromic acid was evolved and the nitrocytosine was recovered unaltered.

2-Oxy-5-nitro-6-phenylureapyrimidine,



$$\begin{array}{ll} N = & CNHCONHC_6H_5 \\ | & | \\ CO & CNO_2 \\ | & \| \\ NH - & CH \end{array}$$

.—Molecular proportions of finely pulverized 5-nitrocytosine and phenylisocyanate were heated together, at 100°, for several hours. The reaction was, apparently, perfectly smooth. When it was complete the urea was washed with alcohol, to remove any unaltered phenylisocyanate and then with cold, 20 per cent hydrochloric acid, to remove unaltered nitrocytosine. It was then thoroughly washed with water and dried at 100°. It was practically insoluble in all solvents and slowly decomposed, without melting, when heated above 215°. Analysis (Kjeldahl):

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[1] Wheeler and Johnson: *Loc. cit.*

	Calculated for $C_{11}H_9O_4N_5$.	Found.
N	25.45	25.9

Action of Acetic Anhydride on Nitrocytosine.—5-Nitrocytosine does not react in a smooth manner with acetic anhydride. When boiled with the anhydride it slowly dissolves to a yellow solution that assumes a red color on prolonged boiling. Different products are formed by this treatment and in varying proportions, depending upon the quantity of anhydride used and on the length of time of boiling. In every experiment that we performed we invariably obtained mixtures of a monoacetyl and a diacetyl derivative, with unaltered material. It was extremely difficult to obtain conditions favorable for the formation of a single acetyl compound.

In one experiment 0.5 gram of nitrocytosine was dissolved in 8 cc. of boiling acetic anhydride. The solution was then immediately cooled, when we obtained a deposit of lenticular shaped crystals. They were soluble in hot water and deposited, on cooling, in prisms. When crystallized a second time the material deposited in fern-like forms that began to darken at 205° and decomposed at about 260°, without effervescence. Analysis (Kjeldahl):

	Calculated for $C_6H_6O_4N_4$.	Found.
N	28.28	28.35

In two other experiments we duplicated the above conditions, except that we boiled the anhydride solution for a longer time. We obtained material that deposited from water in prismatic crystals. While the crystalline form suggested purity, the melting points were unsatisfactory and the nitrogen determinations indicated that we were dealing with a mixture of about equal proportions of a monoacetyl and a diacetyl derivative. The material that was analyzed decomposed at 206°–208°, with effervescence.

	Calculated for			Found.	
	$C_4H_6O_4N_4$.	$C_8H_8O_5N_4$.	Average.	I.	II.
N	28.28	23.33	25.8	26.0	25.81

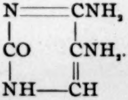
In another experiment we used freshly distilled acetic anhydride. One and seven-tenths grams of the nitropyrimidine were suspended in 10 cc. of the anhydride and the mixture boiled until the pyrimidine completely dissolved. Upon cooling, 1.3 grams of material deposited. It was difficultly soluble in hot water and deposited, on cooling, in needle-like prisms that decomposed at 273°–275°, with violent effervescence. A nitrogen determination agreed with the calculated value for a diacetyl derivative:

	Calculated for $C_8H_8O_5N_4$.	Found.
N	23.33	23.23

The original anhydride filtrate was allowed to evaporate to dryness. We obtained a crystalline residue that proved to be a mixture. After several recrystallizations from water we finally isolated a product that possessed all the properties of the original 5-nitrocytosine. Analysis (Kjeldahl):

	Calculated for $C_4H_4O_3N_4$.	Found.
N	35.89	35.3

2-Oxy-5,6-diaminopyrimidine,



$$\begin{array}{lcl} N & = & CNH_2 \\ | & & | \\ CO & & CNH_2 \\ | & & \| \\ NH & - & CH \end{array}$$

$.H_2O$.—This pyrimidine was formed by reducing 5-nitrocytosine with aluminium amalgam. We had great difficulty in preparing this base and it was only after obtaining negative results from several experiments that we eventually found conditions under which it was possible to isolate it. We finally succeeded in making the compound in the following manner: Three grams of finely pulverized 5-nitrocytosine were suspended in cold water, in contact with aluminium amalgam. The temperature of the solution was not allowed to rise above 35° during the reduction, and the

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mixture was thoroughly agitated in order to disintegrate the coarser particles of the nitropyrimidine. In about 30 minutes the nitropyrimidine had completely dissolved and the reduction was complete. During the reduction we did not detect the presence of ammonia, but after the reduction was finished it was noticeable, indicating a partial decomposition of the diamino derivative. In order to avoid decomposition we quickly filtered from aluminium hydroxide, when we obtained a clear, straw-colored solution. This gradually assumed a dark color when exposed to the air. In order to isolate the pyrimidine base, the solution was concentrated to a small volume by slow evaporation, under diminished pressure. The temperature was kept below 50° and a slow stream of dry hydrogen was passed continually through the capillary tube to avoid oxidation. Considerable amorphous material deposited. After concentrating to about 10 cc., the dark colored solution was filtered and allowed to stand in an ice chest, for 2 days. We obtained a deposit of amorphous substance associated with clusters of radiating prisms. The prisms were carefully removed and washed with cold water. They decomposed when heated above 230° and contained water of crystallization. For analysis they were dried in the atmosphere.

The water of crystallization was determined by heating at 120°-130°, for 1 hour.

0.1124 gram substance lost 0.0163 gram H_2O.

	Calculated for $C_4H_6ON_4.H_2O$.	Found.
N	12.50	14.50

A determination of nitrogen in the anhydrous material gave the following result (Kjeldahl).

	Calculated for $C_4H_6ON_4$.	Found.
N	44.44	44.00

This base was, apparently, quite stable after drying in the air, but when dissolved in water it slowly decomposed with separation of amorphous material. It behaved in every respect like an orthodiamine. An aqueous solution of the base gave the following characteristic reactions: Potassiobismuth iodide gave an insoluble, red precipitate; platinum and gold chlorides were reduced to metallic platinum and gold; Fehling's solution was reduced at once, and a silver mirror was formed when a solution of the base was added to an ammoniacal solution of silver nitrate.

An aqueous solution of the base gave an alkaline reaction when tested with turmeric and litmus. The base gave no difficultly soluble salts with nitric, hydrochloric and sulphuric acids. It was precipitated by phosphotungstic acid.

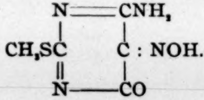
The Picrate of 2-Oxy-5,6-diaminopyrimidine.—This salt deposited from hot water in balls of microscopic prisms. The crystalline form resembled very much that of uracil. It had no definite melting point, but began to turn brown at about 170°, slowly decomposed on further heating, and did not effervesce at 300°. Analysis (Kjeldahl):

	Calculated for $C_4H_6ON_4.C_6H_3O_7N_3$.	Found. I.	 II.
N	27.60	27.67	27.50

The Mercuric Chloride Salt.—This was obtained when mercuric chloride was added to a solution of the base. Analysis (Kjeldahl):

	Calculated for $C_4H_6ON_4.HgCl_2$.	Found.
N	14.1	13.89

2-Methylmercapto-4-oxy-5-nitroso-6-aminopyrimidine,



—Twenty-eight grams of 2-methylmercapto-4-oxy-6-aminopyrimidine[1] and 7.2 grams of sodium hydroxide were dissolved in 450 cc. of water. To this solution was added a concentrated solution of 14 grams of sodium nitrite and then, slowly, 24 grams of glacial acetic acid. The mixture was allowed to stand for 2 hours, when the nitroso derivative deposited as a yellow, crystalline precipitate. After thoroughly washing with cold water, alcohol and ether the crude material was used for the following preparation:

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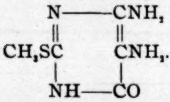
[1] Johnson and Johns: *Loc. cit.*

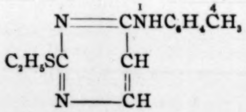
2-Methylmercapto-4-oxy-5,6-diaminopyrimidine,



.—This compound was prepared by reducing the above nitroso derivative with ammonium sulphide. The base deposited from water in needle-like prisms that melted at 215°–216°, with effervescence. It was very soluble in alcohol. It was unstable and gradually assumed a red color when exposed to the air. Analysis (Kjeldahl):

	Calculated for $C_5H_8ON_4S$.	Found.
N	32.55	32.15

2-Ethylmercapto-6-paratoluidinopyrimidine,

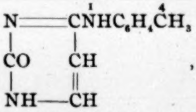


.—This compound was prepared by dissolving 2-ethylmercapto-6-chlorpyrimidine and paratoluidine in dry benzene, in the proper proportions, and warming the solution for several hours on the steam-bath. The excess of benzene was then evaporated on the steam-bath and the pyrimidine purified in the form of its hydrochloride. This deposited from dilute hydrochloric acid in needles that decomposed at 198°–207°, with effervescence. The salt was soluble in hot alcohol and deposited, on cooling, in needles. Analysis (Kjeldahl):

	Calculated for $C_{13}H_{15}N_3S.HCl$.	Found.
N	14.92	14.87

The free base was obtained when the hydrochloride was treated with aqueous ammonia. It separated as a pasty mass, which finally solidified. It deposited from petroleum ether in prismatic crystals that melted, at 104°, to a clear oil. They were extremely soluble in alcohol and benzene. Analysis (Kjeldahl):

	Calculated for $C_{13}H_{15}N_3S$.	Found.
N	17.14	16.93

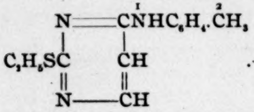
2-Oxy-6-paratoluidinopyrimidine,  , was obtained in the form of its hydrochloride by boiling 2-ethylmercapto-6-paratoluidinopyrimidine with concentrated hydrochloric acid until ethylmercaptan ceased to be evolved. It deposited from alcohol in microscopic prisms that decomposed between 180°-190°, with effervescence. It was soluble in hot water. Analysis (Kjeldahl):

	Calculated for $C_{11}H_{11}ON_3.HCl$.	Found.
N	17.68	17.81

When an aqueous solution of this hydrochloric acid salt was treated with ammonia the free base separated as a crystalline precipitate. It was insoluble in hot water and the ordinary organic solvents, but was purified for analysis by prolonged extraction with hot water. It decomposed slowly when heated above 280° and then melted, to a dark colored oil, at 288°-289°, with violent effervescence. Analysis (Kjeldahl):

	Calculated for $C_{11}H_{11}ON_3$.	Found.
N	20.89	20.71

2-Ethylmercapto-6-orthotoluidinopyrimidine,

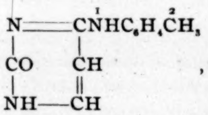


.—From 2-ethylmercapto-6-chlorpyrimidine and orthotoluidine. Its hydrochloride deposited from dilute hydrochloric acid in granular crystals that melted at 230°-232°, with effervescence. Analysis (Kjeldahl):

	Calculated for $C_{13}H_{15}N_3S.HCl$.	Found.
N	14.92	14.63

When an aqueous solution of the hydrochloride was treated with ammonia the base separated as an oil which solidified on standing. It deposited from alcohol in prisms that melted, at 87°, to a clear oil. Analysis (Kjeldahl):

	Calculated for $C_{13}H_{15}N_3S$.	Found.
N	17.14	17.04



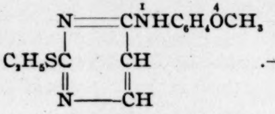
2-Oxy-6-orthotoluidinopyrimidine, , was prepared by boiling 2-ethylmercapto-6-orthotoluidinopyrimidine with hydrochloric acid. The hydrochloride was very soluble in water but insoluble in benzene and acetone. It was purified for analysis by crystallizing from 95 per cent alcohol. It deposited in lenticular shaped crystals that decomposed at 227°-231°, with effervescence. Analysis (Kjeldahl):

	Calculated for $C_{11}H_{11}ON_3.HCl$.	Found.
N	17.68	17.35

The pyrimidine base was insoluble in cold water. It deposited from hot water in radiating prisms that decomposed at 262°. Analysis (Kjeldahl):

	Calculated for $C_{11}H_{11}ON_3$.	Found.
N	20.89	21.05

2-Ethylmercapto-6-paraanisidinopyrimidine,

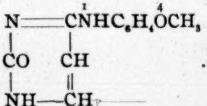


.—From 2-ethylmercapto-6-chlorpyrimidine and paraanisidine. The hydrochloride of this base deposited from hot water in needles that melted at 200°-201°, with effervescence, to an oil. Analysis (Kjeldahl):

	Calculated for $C_{13}H_{15}ON_3S.HCl$.	Found.
N	14.11	14.11

When the salt was treated with ammonia the base was obtained as an oil, that did not solidify after standing for several weeks.

2-Oxy-6-paraanisidinopyrimidine,



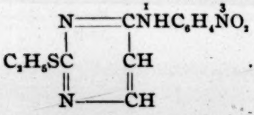
.— The hydrochloride deposited from water in small, radiating needles. It was purified for analysis by recrystallizing from alcohol that was acidified with hydrochloric acid. It decomposed between 145° and 165°, with effervescence. Analysis (Kjeldahl):

	Calculated for $C_{11}H_{11}O_2N_3.HCl$.	Found. I.	II.
N	16.56	16.72	16.65

The free base was difficultly soluble in all ordinary media and showed no crystalline form. It was purified for analysis by drying at 110°, for 2 hours. It melted at 262°. Analysis (Kjeldahl):

	Calculated for $C_{11}H_{11}O_2N_3$.	Found. I.	II.
N	19.35	19.68	19.53

2-Ethylmercapto-6-metanitroanilinopyrimidine,



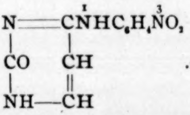
. — From 2-ethylmercapto-6-chlorpyrimidine and metanitroaniline. In this experiment we observed that the free base could be more easily purified than its hydrochloric acid salt. It was insoluble in water and soluble in alcohol. It melted at 175°. Analysis (Kjeldahl):

	Calculated for $C_{12}H_{12}O_2N_4S$.	Found. I.	II.
N	20.29	20.6	20.13

The hydrochloride was prepared by dissolving the base in dilute hydrochloric acid. It deposited in needles that decomposed at 140°–155°, with effervescence. Analysis (Kjeldahl):

	Calculated for $C_{12}H_{12}O_2N_4S.\ HCl$.	Found. I.	Found. II.
N	17.92	17.5	17.67

2-Oxy-6-metanitroanilinopyrimidine,



.—This compound could not be obtained in the usual manner by boiling the above 2-ethylmercapto-6-metanitroanilinopyrimidine with hydrochloric acid. The mercaptopyrimidine was recovered unaltered after boiling with concentrated hydrochloric acid for 15 hours. In order to remove the mercapto radical it was necessary to boil with hydrobromic acid. The hydrobromide was purified by crystallization from 95 per cent alcohol. It decomposed between 160° and 180°, with effervescence. When the salt was treated with alcoholic ammonia the pyrimidine base separated in needle-like prisms. They decomposed when heated above 275°. Analysis (Kjeldahl):

	Calculated for $C_{10}H_8O_3N_4$.	Found.
N	24.14	24.35

NEW HAVEN, CONN.,
June 1, 1906.

THE REACTION BETWEEN UNSATURATED COMPOUNDS AND ORGANIC MAGNESIUM COMPOUNDS.

IX. REACTIONS WITH STEREOISOMERS.

BY E. P. KOHLER.

In the last paper[1] it was shown that two racemic products are obtained whenever the addition of an organic magnesium compound to an unsaturated nitrile results in substances containing two unequal, asymmetric carbon atoms. Most of the substances of this type have heretofore been made by one of two methods; by addition to ethylene derivatives, or by the interaction of two substances of which each contained one asymmetric carbon atom. By the first of these methods the two asymmetric carbon atoms are generated simultaneously; two racemic modifications are formed, but generally in very unequal quantities. It is known[1] that the second method also gives two racemic modifications, but there are no results that show the relative amounts.

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[1] THIS JOURNAL, 35, 386.

When substances containing two asymmetric carbon atoms are obtained by the addition of Grignard's reagent to unsaturated compounds, the asymmetry is established in steps:

$$C_6H_5CH : C(C_6H_5)COC_6H_5 \longrightarrow$$

$$C_6H_5\overset{*}{C}H(C_2H_5)C(C_6H_5) : C(OH)C_6H_5 \longrightarrow$$

$$C_6H_5\overset{*}{C}H(C_2H_5)\overset{*}{C}H(C_6H_5)COC_6H_5.$$

For the purpose of explaining the mechanism of 1,4-addition it is important to determine, as far as possible, the manner in which the asymmetry is produced. The possibilities are as follows:

1. The addition of the reagent results in the formation of two ethylene isomers which, on rearrangement, pass into the corresponding optical antipodes. The direct product of addition would, in this case, contain four substances, because each ethylene isomer would be a racemic modification containing one asymmetric carbon atom.

2. The addition product contains but one racemic ethylene derivative, the two components forming two pairs of antipodes during rearrangement.

3. The entire reaction results in but one racemic modification, the second being due to autoracemization, which takes place very readily when an asymmetric carbon atom holds mobile hydrogen.

These possibilities could not be examined with the nitriles discussed in the previous paper, because the results are complicated by the presence of the triple linkage in cyanogen. It was necessary, therefore, to repeat the experiments, using ketones in place of nitriles, and in order to make the results as general as possible it was desirable to use ethylene isomers. Benzal- and *iso*-benzaldeoxybenzoin, the best known pair of stereoisomeric ketones, were found to serve admirably for this purpose. Nearly all the reactions are perfectly clean and the products solids, hence it was possible to account for all of the materials used.

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[1] Kipping and Salway: J. Chem. Soc., **85**, 438.

To test the first assumption, equal quantities of the two ketones were added to ethylmagnesium bromide, in carefully cooled and in boiling ethereal solution. As the resulting magnesium derivatives could not be examined directly, it was necessary to transform them into more stable substances with the same structure. For this purpose the ethereal solutions were cooled in freezing mixtures and treated with acid chlorides:

$$C_6H_5CH(C_2H_5)C(C_6H_5) : C(C_6H_5)OMgBr + RCOCl = C_6H_5CH(C_2H_5)C(C_6H_5) : C(C_6H_5)OCOR.$$

The same acyl derivative was obtained, in calculated quantity, from both ketones. This result indicates that but one magnesium derivative is formed, because it is improbable that, under the conditions of the experiment, the reaction with acid chlorides is accompanied by rearrangement. Other results described below lead to the same conclusion.

To test the second assumption, both the magnesium and the acyl derivatives were hydrolyzed. All of these substances should give the diphenylbutyrophenone, of which two racemic modifications were described in an earlier paper. It was found that when the magnesium derivative is decomposed with ice water, in the usual way, 80 per cent of the product consists of the low-melting and the remainder of the high-melting modification of this ketone, while the acetyl and benzoyl derivatives, on hydrolysis with acids or bases, give only the high-melting modification. The apparent contradiction between these results was removed by the discovery that the low-melting ketone passes into its isomer so readily, that only the latter could be expected when the acyl derivatives are hydrolyzed by boiling with acids or bases.

The unusual ease with which one of these ketones is transformed into the other suggests the possibility that the low-melting ketone is the sole product formed by decomposing the magnesium derivative, and that the relatively small quantity of the high-melting isomer is due to subsequent racemization, I believe that such is the case, for although it was not possible to direct the reaction in such a way as to get only one product, it was found that the relative amounts of the two ketones obtained depend entirely upon the mode of hydrolysis, and that when the conditions are least favorable to racemization the yield of high-melting ketone is less than 0.5 per cent.

It is probable, therefore, that but one substance is formed in the process :

$$C_2H_5\overset{*}{C}H(C_6H_5)\underset{\text{I.}}{C(C_6H_5)} : C(OH)C_6H_5 \rightarrow$$

$$C_2H_5\overset{*}{C}H(C_6H_5)\overset{*}{C}H(C_6H_5)COC_6H_5.$$

II.

It is not difficult to explain such a result. The ethylene derivative (I.) is composed of two optical isomers containing one asymmetric carbon atom. In the sugars, as Fischer discovered,[1] additions to optically active substances may take place asymmetrically, the active group exercising a directing influence upon the addend. Later observations,[2] and particularly the recent success[3] in achieving "asymmetric synthesis," indicate that this mode of addition is not exceptional. It is probable, therefore, that in a rearrangement like that under consideration, the active group containing the asymmetric carbon would exercise a similar influence upon the shifting hydrogen. This would necessarily give the result obtained. If we represent the two asymmetric carbon atoms in the product by a and b, and the ethylene derivative by *d*a + *l*a, then the ketone obtained from *d*a may be either *d*a*d*b or *d*a*l*b. If the former represents the product from *d*a, then the product from *l*a must be *l*a*l*b, because the directive influence is opposite in character. Similarly, if the product in the first case is *d*a*l*b, then the product from *l*a must be *l*a*d*b. In either case only one inactive substance should be obtained :

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[1] Ber. d. chem. Ges., 22, 370. Ann. Chem. (Liebig), 270, 68.

[2] Ber. d. chem. Ges., 37, 2486.

[3] J. Chem. Soc., 85, 1249; 87, 1373; 89, 365.

*d*a*d*b + *l*a*l*b or *d*a*l*b + *l*a*d*b.

A study of oxymethylene compounds, led Claisen[1] to the conclusion that the presence of phenyl groups in certain positions favors enolic modifications. To account for the anomalous behavior of diphenylacetaldehyde, for example, he suggested the formula $(C_6H_5)_2C:CHOH$ instead of $(C_6H_5)_2CHCHO$. Similarly Biltz,[2] after a careful investigation of triphenylethane derivatives, suggested that the substance previously regarded as diphenylacetophenone was, in reality, an enolic compound, $(C_6H_5)_2C:C(C_6H_5)OH$, instead of $(C_6H_5)_2CHCOC_6H_5$. In view of these conclusions it seemed worth while to try to isolate some of the enols which, as I have assumed, are formed when the magnesium derivatives, obtained from unsaturated compounds, are decomposed with water. Only one of the many experiments made in this direction was completely successful. In the case of tetraphenylpropenol it was possible to isolate the pure substance in crystalline form, to prove its structure, and to observe the transition into the isomeric triphenylpropiophenone :

$$(C_6H_5)_2CHC(C_6H_5):C(C_6H_5)OH \longrightarrow (C_6H_5)_2CHCH(C_6H_5)COC_6H_5.$$

In other cases, where the enols could not be obtained in a solid form, it was possible to detect their presence in solution, and even to follow the gradual transformation into ketones.

The most striking property of these unsaturated alcohols is their pronounced tendency to combine with free oxygen and form peroxides. Autoxydation has been observed in a number of ethylene derivatives, but it has not been possible, heretofore, to get definite peroxides whose structure could be determined. The peroxides described in this paper are crystalline solids, sufficiently stable for direct analysis and for the determination of molecular weights. The reactions show that they are represented by the general formula

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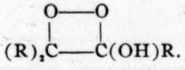
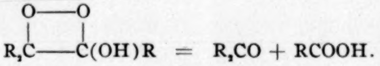
[1] Ber. d. chem. Ges., **25**, 1761.

[2] Ann. Chem. (Liebig), **296**, 242. Ber. d. chem. Ges., **32**, 650.



$$(R)_2C(-O-O-)C(OH)R.$$

They decompose in solution, or at high temperatures, according to the equation :



$$R_2C(-O-O-)C(OH)R = R_2CO + RCOOH.$$

EXPERIMENTAL PART.

The large quantity of deoxybenzoin needed for the following experiments was made from benzoin by a combination of the methods recently proposed by Sudborough[1] and by Stobbe and Straus.[2] A solution of 100 grams of benzoin, in 500 grams of glacial acetic acid, was treated with 75 grams of zinc dust and the mixture heated on a water-bath for 24 hours. The undissolved zinc dust was removed by filtration while the liquid was hot, the filtrate poured into water and allowed to stand until the precipitated oil had solidified. The solid was washed with water and digested with 250 cc. of ether. This dissolved all of the deoxybenzoin, but left a considerable quantity of more complex products. After filtration, the ethereal solution was dried over calcium chloride, the ether evaporated and the residue distilled, as recommended by Stobbe and Straus. The yield of pure ketone was 65 to 70 per cent of the calculated amount.

The isomeric ketones were made from deoxybenzoin by the method of Stobbe and Niedenzu,[3] but it was found much better to operate at a higher temperature. No addition product with hydrochloric acid is formed when the condensation is carried out at 100°, hence it is possible to avoid the irksome removal of excess of benzaldehyde with bisulphite and to purify the product by distillation under diminished pressure. The procedure was as follows : A moderately rapid current of dry hydrogen chloride was passed, for 2–4 hours, through a mixture of equal weights of benzaldehyde and deoxybenzoin, contained in a Claisen distilling flask that was heated with boiling water. The flask was then connected with a pump, the pale yellow liquid freed from hydrochloric acid and water, and the residue distilled under diminished pressure. The distillate was collected in 3 fractions. The first, collected to 160° (11 mm.) contained almost pure benzaldehyde.

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[1] J. Chem. Soc., 71, 219.

[2] Ann. Chem. (Liebig), 319, 163.

[3] Ber. d. chem. Ges., 34, 3900.

The second, 160°–230°, solidified in the receiver. It contained, besides small quantities of stilbene and unsaturated ketone, mainly deoxybenzoin, which was easily recovered by distillation and crystallization from alcohol. The remainder of the liquid distilled almost completely between 230°–260°. The yellow to orange distillate was poured into three times its volume of absolute alcohol and the solid that separated recrystallized from alcohol until free from color. The mixture of the two ketones obtained in this way was easily separated by crystallization from a mixture of ether and ligroin, as recommended by Stobbe and Niedenzu, or from acetone and alcohol as proposed by Klingemann.[1] The yield was good—100 grams of deoxybenzoin gave 96 grams of the mixed ketones and 10 grams of unchanged deoxybenzoin. The composition of the mixture depends upon the length of time employed in the condensation. Thus, 50 grams obtained by heating for 2 hours, contained 28 grams of the high-melting ketone, while the same amount, obtained by heating for 5 hours, contained 43 grams. The relatively large amount of the high-melting ketone obtained in these experiments is due to rearrangement during distillation. When the product, obtained from 100 grams of deoxybenzoin by heating for 2 hours, was separated by crystallization instead of by distillation, it gave 72 grams of the low-melting ketone.

Reactions with Magnesium Compounds.

Stobbe and Niedenzu compared the behavior of the two isomeric ketones with various reagents—bromine, hydrochloric acid, deoxybenzoin—which combine with unsaturated compounds. They found that the reactions took place slowly, were always incomplete and were accompanied by rearrangement; that the high melting ketone combined more readily than its isomer and that both ketones invariably gave the same product. The reactions with organic magnesium compounds proceed rapidly and they are complete, but the products from both ketones are likewise the same. This conclusion was established as follows: Cooled, ethereal solutions, containing 5 grams of the ketones, were added, drop by drop, to similar solutions of ethylmagnesium bromide that were cooled in a freezing mixture. Each drop of the solutions produced a yellow precipitate, which disappeared on shaking. The resulting solutions were decomposed with iced hydrochloric acid, the ethereal layers washed thoroughly with ice-water, then mixed with 50 cc. of alcohol for the purpose of preventing the formation of peroxides and evaporated to crystallization on the water-bath. Each of the ketones gave a mixture of the two stereoisomeric modifications of diphenylvalerophenone that were described in an earlier paper.[1] The total yields were 6.2 grams and 6.3 grams, in place of 6.5 grams calculated. The mixtures were separated by extraction with cold alcohol, in which the high-melting ketone is very sparingly soluble. The product from benzaldeoxybenzoin gave 5.1 grams of low-melting and 0.8 gram of high-melting ketones, while the product from *iso*-benzaldeoxybenzoin gave 5.3 grams and 0.7 gram of the substances.

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[1] Ann. Chem. (Liebig), 275, 64.

By changing the conditions it was found that the relative amounts of the two products depend solely upon the method of isolation. When the solid ketones were added to boiling solutions and the products isolated as in the first experiment, the relative amounts of stereoisomers obtained were almost the same as before—5 grams of low-melting and 0.9 gram of high-melting in one case and 4.9 grams and 1.0 gram in the other. But when the reactions were carried out in a freezing mixture, as in the first experiment, and the magnesium derivatives poured into water instead of iced hydrochloric acid, the relative quantities were quite different, 3 grams of low-melting to 3.1 grams of high-melting in one case and 2.5 grams to 3.8 grams in the other. In view of these results it seemed probable that the two isomeric products had been formed from the same magnesium derivative. To test this view, ethereal solutions of the magnesium derivative were prepared as described in the first experiment and treated, in a freezing mixture, with a cold, dilute solution containing one molecule of benzoyl chloride for each atom of magnesium used in the preparation of the ethylmagnesium bromide. Only one benzoyl derivative was formed and this was obtained in calculated quantity from both ketones.

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[1] THIS JOURNAL, 35, 399.

Triphenylpentenyl Benzoate, $C_2H_5CH(C_6H_5)C(C_6H_5):C(C_6H_5)OCOC_6H_5$.—The crude product, isolated in the usual way, was purified by crystallization from absolute alcohol. It separated in long needles, melting at 143°. Analysis:

0.1321 gram substance gave 0.4165 gram CO_2 and 0.0747 gram H_2O.

	Calculated for $C_{30}H_{26}O_2$.	Found.
C	86.1	85.91
H	6.2	6.28

The compound is readily soluble in acetone and chloroform, moderately in boiling alcohol, sparingly in cold alcohol and ligroin. It seems to represent the stable modification, as no change took place when it was heated to 150° for 40 hours, nor when a solution in benzene was exposed to sunlight, in the presence of iodine. It is very easy to hydrolyze the substance. A saturated, alcoholic solution was treated with the calculated quantity of aqueous potassium hydroxide and the mixture placed in an ice chest. In the course of an hour the high-melting form of diphenylvalerophenone began to separate and at the end of 5 hours the solution was neutral to litmus. The liquid was then poured on ice, the solid dried and extracted with ligroin. Not a trace of low-melting ketone went into solution. The same product was obtained when the substance was heated to 150°, with concentrated hydrochloric acid, but the result was somewhat different when the ester was boiled with an alcoholic solution of the acid, the product in this case containing nearly 10 per cent of low-melting ketone. With cold, alcoholic hydrochloric acid a still larger amount, 14 per cent, of this ketone was formed. These results seemed to indicate that the low-melting ketone is the primary product of hydrolysis—the isomer being due to subsequent rearrangement. Parallel tests were therefore made with alcoholic solutions of these two ketones, both in the presence of bases and of acids. It was found that, in the presence of potassium hydroxide, the low-melting ketone passes rapidly and completely into its isomer even in a freezing mixture and that the same change takes place more slowly, but just as completely, in the presence of hydrochloric acid. The high-melting ketone, of course, remained unchanged. The presence of the low-melting ketone in the products of hydrolysis proves, consequently, that this is the primary product of that reaction.

Triphenylpentenylacetate, $C_2H_5CH(C_6H_5)C(C_6H_5) : C(C_6H_5)OCOCH_3$.—This ester was made and purified like the corresponding benzoate. The same substance was obtained from both unsaturated ketones. It crystallizes in fine needles, melting at 120°, is readily soluble in acetone, chloroform and boiling alcohol and, on hydrolysis, behaves exactly like the corresponding benzoate. Analysis:

0.1221 gram substance gave 0.3761 gram CO_2 and 0.0760 gram H_2O.

	Calculated for $C_{25}H_{24}O_2$.	Found.
C	84.26	84.01
H	6.74	6.91

All the results described up to this point were obtained with each of the unsaturated ketones. As they show conclusively that both ketones invariably give the same products, the subsequent experiments were performed only with one or other, or, frequently, with a mixture of the two substances. The simplest interpretation of these results is as follows: Both of the unsaturated ketones combine with ethylmagnesium bromide to form the same magnesium derivative of triphenylpropenol. From this magnesium derivative acids liberate the corresponding modification of the unsaturated alcohol, while acid chlorides form its esters. The esters, on hydrolysis, give the same unsaturated alcohol and this, on rearrangement to ketone, gives only the low-melting form of diphenylvalerophenone, which subsequently passes, more or less completely, into its stereoisomer. The evidence in favor of this view, while strong, is not conclusive, because not a single experiment gave only the low-melting ketone. I therefore endeavored to isolate the enol itself.

For this purpose the magnesium derivative, prepared as in previous experiments, was poured on cracked ice that was covered with alcohol-free ether, the basic magnesium salt was dissolved with a freezing mixture of ice and hydrochloric acid and the ethereal layer washed, as quickly as possible, with small quantities of ice water. The moist, ethereal solution was then transferred to a distilling flask immersed in a freezing mixture and the ether evaporated under diminished pressure. The colorless oil that was left was evidently the unsaturated alcohol. It was readily and completely soluble in cold, low-boiling ligroin, in which the isomeric ketones are insoluble, and it reduced an acetone solution of potassium permanganate, which is not attacked by the ketones. All efforts to get the substance in a solid form, in which it might have a moderate degree of stability, failed. When allowed to stand in a freezing mixture it slowly solidifies, but the solid does not reduce permanganate. The composition of this solid, however, fully confirms the interpretation offered above. Forty-five grams, obtained by combining the products of 4 experiments, gave only 0.17 gram of high-melting diphenylbutyrophenone, all of the remainder being the low-melting isomer.

Since the enol could not be isolated in the solid form, it was necessary to find some reagent by which it could be separated from the isomeric ketones. It reduces potassium permanganate, but the process is accompanied by rearrangement and the product bears no simple relation to the original substance. Although unsaturated, the enol does not combine with either bromine or hydrochloric acid and in the presence of traces of these substances it rapidly passes into the isomeric ketones. After many fruitless experiments it was found that the unsaturated alcohol readily combines with atmospheric oxygen, and that this admirably serves the purpose of a reagent. The procedure is as follows: The moist, ethereal solution of the unsaturated alcohol, prepared as already described, is transferred to a filter flask that is immersed in a freezing mixture. A rapid current of air is drawn through the liquid for several hours, the evaporated ether being replaced from time to time either with more anhydrous ether, or with low-boiling ligroin. If the product is oily it is dissolved in low-boiling ligroin. From this solution the peroxides always separate, on slow evaporation, in a crystalline form.

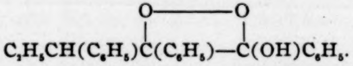
The oxygen addition product from triphenylpentenol solidified to a hard, colorless cake. This was ground up, washed with small quantities of absolute alcohol to remove adherent moisture, and dissolved in acetone. The first crop of crystals separated in thick needles which, after a second crystallization from the same solvent, melted sharply at 166° and decomposed immediately after melting. The filtrates from these needles contained a second substance that separated slowly, in large, transparent prisms. This was purified by recrystallization from ligroin. It melts at 109°. Analysis of these products showed that they are isomeric, and a molecular weight determination, carried out in boiling acetone, showed that both are monomolecular.

I. 0.1360 gram substance (166°) gave 0.3980 gram CO_2 and 0.0782 gram H_2O.

II. 0.1161 gram substance (110°) gave 0.3388 gram CO_2 and 0.0674 gram H_2O.

	Calculated for $C_{23}H_{22}O_3$.	Found. I.	Found. II.
C	79.79	79.82	79.59
H	6.36	6.40	6.44

The substances are evidently formed by the addition of a molecule of oxygen either to triphenylpentenol or to the isomeric ketones. Parallel experiments showed that no peroxides are formed when air or oxygen is passed through cooled, ethereal solutions of the ketones, and another set of experiments proved that the product of the reaction with ethylmagnesium bromide contains no substance that might act as a catalyst in the autoxydation of the ketones. These experiments were conducted as follows: An ethereal solution, made from 15 grams of deoxybenzoin, was diluted to 240 cc. with absolute ether and divided into 3 equal portions. After adding 5 grams of low-melting ketone to one of these and the same weight of high-melting to another, a current of air was passed through all three. The solution to which no ketone had been added gave 6.3 grams of crude, dry peroxide. The second solution deposited a mixture of low-melting ketone and peroxide. The latter was destroyed with boiling, alcoholic hydrochloric acid and the residue extracted with cold ligroin. This left 4.87 grams of ketone instead of 5 grams originally added. Since the third portion, after similar treatment, left 4.92 grams of ketone, it is evident that the isomeric peroxides are not derived from the ketones but from the unsaturated alcohol. This gives, as the most probable formula,



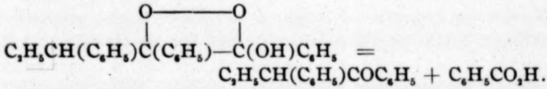
$$\mathrm{C_2H_5CH(C_6H_5)\overset{\overset{O}{|}}{C}(C_6H_5)\!-\!\overset{\overset{O}{|}}{C}(OH)C_6H_5.}$$

The peroxides from triphenylpentenol are stable substances. They do not give hydrogen peroxide with water, do not liberate iodine from iodides, nor give up oxygen to indigo. When perfectly pure they are not changed by air or direct sunlight, but, in the presence of minute quantities of impurities, they gradually become yellow and ultimately turn into gums. When heated in quantity they decompose with a flash, but without detonation. For the purpose of determining the products of decomposition, 5 grams of each were dropped, in small portions, into flasks heated to 170°, in an oil-bath. The pale-yellow products were dissolved in ether, the solution extracted with aqueous sodium carbonate and the ether evaporated. From the solution in sodium carbonate hydrochloric acid precipitated pure benzoic acid. The ethereal solution, in each case, left an oil which ultimately solidified. The solids, after recrystallization from ligroin, melted at 58°, the same products being obtained from both peroxides. Analysis:

0.1302 gram substance gave 0.4082 gram CO_2 and 0.0855 gram H_2O.

	Calculated for $C_{16}H_{16}O$.	Found.
C	85.71	85.42
H	7.14	7.22

The composition and melting point indicated ethyldeoxybenzoin. This was confirmed by making the oxime, which melted at 130°. The decomposition by heat is, therefore, similar to that of the ozonides described by Harries.[1] It is represented by the equation :



$$\mathrm{C_2H_5CH(C_6H_5)\overset{O-}{C}(C_6H_5)-\overset{-O}{C}(OH)C_6H_5} = \mathrm{C_2H_5CH(C_6H_5)COC_6H_5 + C_6H_5CO_2H}.$$

In solution the same decomposition takes place at much lower temperatures and it is accelerated both by acids and by bases. From a solution in absolute alcohol, which contained one equivalent of potassium hydroxide for one of peroxide, potassium benzoate began to separate, at the ordinary temperature, in less than half an hour and at the end of 3 hours the liquid was neutral.

Owing to the ease with which the peroxides decompose it was not possible to make an acetyl derivative either with acetyl chloride or acetic anhydride, but the presence of hydroxyl was easily established with ethylmagnesium bromide. A solution of the reagent was slowly siphoned into an ethereal solution containing excess of the peroxide (166°). The reaction was accompanied by a steady evolution of gas, and almost the entire amount of peroxide was recovered when the product was decomposed with ice.

The formula proposed accounts for these reactions and also for the formation of two isomeric peroxides. It contains 3 unequal, asymmetric carbon atoms, but since the reaction is accompanied by ring formation, only *cis*-addition of oxygen is to be expected. With an inactive substance containing one asymmetric carbon atom this process would result in two racemic modifications.

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[1] Ann. Chem. (Liebig), 343, 311.

With the help of these peroxides it was possible to make a rough estimate of the rate at which triphenylpentenol passes into the isomeric ketones. An ethereal solution, containing approximately 25 grams of the alcohol, was diluted to 500 cc. and placed in an ice-chest. At intervals, 100 cc. of the solution were drawn off with a pipette and evaporated in a current of air. The solid residue was boiled with alcoholic hydrochloric acid, to destroy any peroxide formed, and the alcohol evaporated to dryness. By extracting the residue with cold methyl alcohol, ethyldeoxybenzoin could be removed without losing more than a trace of diphenylvalerophenone (170°). The first trial, made immediately after preparing the solution, gave only 0.3 gram of ketone, showing that almost no rearrangement had taken place when the magnesium compound was decomposed with water. The remaining tests gave the following results: After 10 hours, 2.1 grams of ketone; 24 hours, 4.4 grams; 30 hours, 5.4 grams; 50 hours, 5.25 grams. These numbers represent only very rough approximations; it was not possible to duplicate experiments and get the same results. In one experiment, in which the ethereal solution had been made with the greatest care, no peroxide could be detected after the lapse of 8 hours.

Tetraphenylpropenol, $(C_6H_5)_2CHC(C_6H_5):C(OH)C_6H_5$.—When benzaldeoxybenzoin istreated with phenylmagnesium bromide, the product, isolated in the usual way, is triphenylpropiophenone, which has been described in a previous paper.[1] By bringing the substances together in ligroin, and treating the product as described under the reaction with ethylmagnesium bromide, it was possible to get the intermediate, unsaturated alcohol in a solid form. It separated from ligroin in colorless needles, readily soluble in alcohol and ether, sparingly in ligroin. The melting point observed depends upon the mode of heating, because the substance passes into the ketone below the melting-point. The true melting point probably lies between 95° and 100°, as was found by dipping capillary tubes containing the substance into water at different temperatures. The enol is so sensitive to oxygen that all operations had to be carried out in nitrogen or carbon dioxide. As it rapidly passes into triphenylpropiophenone on heating, it seemed useless to undertake an analysis.

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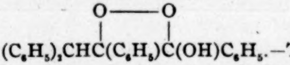
[1] This Journal, 34, 568.

Tetraphenylpropenolperoxide,



$$(C_6H_5)_2CH\overset{\overset{O\text{——}}{|}}{C}(C_6H_5)\overset{\overset{O}{|}}{C}(OH)C_6H_5$$

—The crude product, obtained by passing air through a solution of the alcohol, was purified by crystallization from acetone and ligroin. Analysis:

0.1163 gram substance gave 0.3509 gram CO_2 and 0.0606 gram H_2O.

	Calculated for $C_{27}H_{22}O_3$.	Found.
C	82.21	82.29
H	5.58	5.79

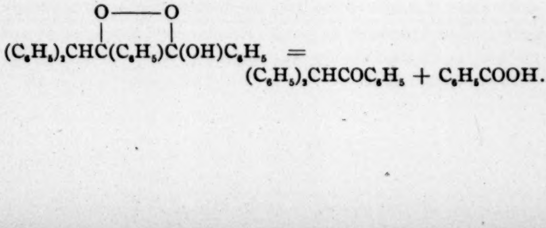
The peroxide crystallizes in small, lustrous prisms that melt at 127°. It is readily soluble in alcohol, ether, chloroform and acetone; sparingly soluble in ligroin. When heated by itself, or with hydrochloric acid in alcoholic solution, it decomposes into benzoic acid and a substance melting at 139°–140°. Analysis:

I. 0.1386 gram substance gave 0.4473 gram CO_2 and 0.0742 gram H_2O.

II. 0.1516 gram substance gave 0.4900 gram CO_2 and 0.0808 gram H_2O.

	Calculated for $C_{20}H_{16}O$.	Found. I.	Found. II.
C	88.23	88.02	88.14
H	5.88	5.94	5.92

By analogy with the behavior of the peroxides previously described the substance would be expected to give diphenylacetophenone, according to the equation:



$$(C_6H_5)_2CH\overset{\overset{O\text{——}}{|}}{C}(C_6H_5)\overset{\overset{O}{|}}{C}(OH)C_6H_5 = (C_6H_5)_2CHCOC_6H_5 + C_6H_5COOH.$$

A compound of this composition was discovered by Delacre,[1] and subsequently studied with care by Gardeur[2] and by Biltz.[3] Gardeur agreed with Delacre and believed that the substance is a ketone, while Biltz regards it as the isomeric unsaturated alcohol. The principal reasons for the latter view are: The instability of the substance in the presence of alcoholic potassium hydroxide, which decomposes it into diphenyl methane and benzoic acid; the ease with which the hydrogen is replaced by bromine; the inability of all investigators to get an oxime; and the fact that Biltz obtained an acetyl derivative by boiling the substance with sodium acetate and acetic anhydride, and the corresponding benzoyl derivative by boiling it with benzoyl chloride and pyridine.

My product is evidently identical with the substance studied by Biltz and by Gardeur. It has the same melting point, gives the same products with alcoholic potassium hydroxide, and an acetyl derivative, melting at 105°, when treated as directed by Biltz. It differs markedly from the enolic compounds considered in this paper, being perfectly stable and incapable of combining with free oxygen. Biltz's view, therefore, seemed open to doubt, the more so because the strongest evidence for the enol formula offered, the formation of acyl derivatives, is invalidated by the more recent discovery that even ketones may give such derivatives when heated with acid chlorides and pyridine.[4]

The most conclusive method for deciding between the two formulas is to study the behavior of the substance towards Grignard's reagent, because it has been shown that substances like acetoacetic ester decompose the reagent like hydroxyl compounds. It was found that no gas is evolved when the substance in question was added to ethylmagnesium bromide. The product of the reaction was a solid, which was purified by crystallization from methyl alcohol. It crystallizes in needles, melting at 91°, and is readily soluble in organic solvents. Analysis:

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[1] Bull. Soc. Chim., [3], **13**, 859.

[2] Centrabl., 1897, II., 660.

[3] Ber. d. chem. Ges., **32**, 650.

[4] Lees: J. Chem. Soc., **190**, 3; **84**, 145. Claisen: Ber. d. chem. Ges., **36**, 3674.

0.1142 gram substance gave 0.3655 gram CO_2 and 0.0755 gram H_2O.

	Calculated for $C_{22}H_{22}O$.	Found.
C	87.41	87.27
H	7.28	7.34

The substance is evidently an alcohol, formed according to the equation:

$$(C_6H_5)_2CHCOC_6H_5 + C_2H_5MgBr + H_2O = (C_6H_5)_2CHC(C_6H_5)(C_2H_5)OH.$$

This conclusion was confirmed by treatment with ethylmagnesium bromide.

Diphenylacetophenone Oxime $(C_6H_5)_2CHC(C_6H_5) : NOH$.—Although Delacre and Biltz failed to get an oxime by boiling the ketone with hydroxylamine hydrochloride, it seemed possible that the substance might be obtained in alkaline solution. Under these conditions a large part of the ketone is destroyed, but the first experiment, in which an alcoholic solution, containing 1 molecule of ketone to 3 molecules of hydroxylamine hydrochloride and 9 molecules of potassium hydroxide, was boiled for an hour, yielded a small quantity of nitrogenous product melting at 180°. The process was repeated many times without getting a trace of this substance, but at last an experiment carried out in the same way gave 1.5 grams, from 5 grams of ketone. The product was purified by recrystallization from acetone, from which it separates in plates. Analysis:

I. 0.0542 gram substance gave 0.2578 gram CO_2 and 0.0463 gram H_2O.

II. 0.4600 gram substance gave 20.8 cc. N at 18° and 754 mm.

	Calculated for $C_{20}H_{17}OH$.	Found.	
		I.	II.
C	83.62	83.41	. .
H	6.06	6.01	. .
N	4.87	. .	5.12

The oxime melts at 182°. It is readily soluble in acetone, sparingly in alcohol. Dilute acids and boiling water quickly hydrolyze it, the sole organic product being triphenylpropiophenone.

Bromtriphenylpropiophenone, $(C_6H_5)_2CHCBr(C_6H_5)COC_6H_5$.—This substance was obtained by treating the magnesium derivative of tetraphenylpropenol with bromine. It was purified by crystallization from a mixture of chloroform and alcohol, from which it separates slowly in large prisms, melting at 124°. It is readily soluble in chloroform, moderately in acetone, very sparingly in alcohol.

0.1515 gram substance gave 0.4088 gram CO_2 and 0.0667 gram H_2O.

	Calculated for $C_{27}H_{21}OBr$.	Found.
C	73.47	73.58
H	4.76	4.88

It is easy to eliminate hydrobromic acid from this substance and thus get a new unsaturated ketone. This is still under investigation.

CHEMICAL LABORATORY,
BRYN MAWR COLLEGE,
May, 1906.

VARIABLE SENSITIVENESS IN COLORIMETRY. II.[1]

BY DAVID W. HORN AND SUE A. BLAKE.

In a previous contribution[2] from this laboratory, it was shown that, at certain definite concentrations, the comparisons in the colorimetric determination of chromium can be made with greater ease and accuracy than at other concentrations. An appreciable difference in color in dilute solutions of potassium chromate and of chromium sulphate is produced, in some cases, by a much smaller weight of chromium than in others. The figures did not show any simple relation, however, between the concentrations of the solutions and the minimum weights of chromium necessary to produce appreciable changes in color.

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[1] Read in abstract before the Philadelphia Section, Amer. Chem. Soc., March 17, 1906.

[2] THIS JOURNAL, 35, 253.

In the present paper the results for potassium chromate, reduced to values suitable for graphic representation, are presented again and discussed along with the results of a study of a second case, that of copper sulphate. Copper sulphate was selected for this study because the color of its solutions is quite different from that of those previously studied, and is due to a kathion.

The experimental results are given in the following tables:

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Table I.—Solutions of Potassium Chromate.

	V.		S.		
Number of experiment. 1.	Concentration stated as liters that contain one gram atom of Cr. 2.	Milligrams of Cr producing a just perceptible difference in color in 50 cc. 3.	Sensitiveness: reciprocals of values found in column 3. 4.	$\frac{\sqrt{V}}{25}$. 5.	$S/_{150}$. 6.
1	250.0	3.979	0.25	0.63	0.002
2	500.0	0.784	1.28	0.90	0.009
3	666.6	0.386	2.59	1.03	0.017
4	1000.0	0.184	5.43	1.26	0.036
5	2000.0	0.074	13.51	1.79	0.090
6	3600.0	0.007	142.86	2.40	0.952
7	4000.0	0.002	500.00	2.53	3.33
8	8000.0	0.001	1000.00	3.58	6.66
9	9900.0	0.005	200.00	3.98	1.33
10	10666.6	0.008	125.00	4.13	0.83
11	16000.0	0.011	90.90	5.06	0.61
12	17700.0	0.003	333.33	5.33	2.22
13	32000.0	0.0007	1428.60	7.16	9.52
14	110000.0	0.011	90.90	13.27	0.61
15	150000.0	0.008	125.00	15.50	0.83
16	200000.0	not distinguishable from distilled water.			

Table II.—Solutions of Copper Sulphate.

Number of experiment. 1.	V. Concentration stated as liters that contain one gram atom of Cu. 2.	Milligrams of Cu producing a just perceptible difference in color in 50 cc. 3.	S. Sensitiveness: reciprocals of values found in column 3. 4.	$\frac{\sqrt{V}}{1.75}$. 5.	S × 7.7. 6.
1	1.64	154.51	0.006	0.71	0.05
2	3.28	77.25	0.013	1.00	0.10
3	24.42	12.36	0.081	2.78	0.62
4	37.99	8.03	0.124	3.57	0.95
5	45.72	5.41	0.185	3.85	1.42
6	52.61	6.18	0.162	4.14	1.25
7	55.64	5.79	0.173	4.28	1.33
8	68.61	3.86	0.259	4.71	2.00
9	69.43	4.63	0.216	4.78	1.66
10	82.28	3.86	0.259	5.21	2.00
11	85.72	3.86	0.259	5.28	2.00
12	91.51	3.86	0.259	5.49	2.00
13	102.91	3.09	0.323	5.78	2.49
14	128.74	2.32	0.431	6.49	3.32
15	164.77	1.16	0.862	7.35	6.64
16	187.06	0.77	1.299	7.85	9.96
17	329.53	1.74	0.575	10.42	5.97
18	748.24	1.93	0.518	15.64	3.99
19	4892.30	just distinguishable from distilled water.			

The values in columns 5 and 6 in Tables I. and II. are represented graphically in Figs. I. and II., respectively. Distances on the horizontal axis are proportional to the square roots of the concentrations, and distances on the vertical axis to the sensitiveness. The *square roots* of concentrations are used to make the graphs less extensive. Solutions of potassium chromate, of concentrations corresponding to the maxima and minima in Fig. I., were examined with a spectrometer; as was anticipated, no measurable differences in the refractive indices were found.

When the two graphs are compared the resemblance between that for copper sulphate solutions and the first part of that for potassium chromate solutions is apparent. This agreement in form was noticed early in the work and suggested that, in both cases, we had to deal with the same phenomena. Experiments 19, Table I., and 15 and 16, Table II., show that the tinctorial power of $\overset{++}{\mathrm{Cu}}$ is only about one-thirtieth that of $\overset{=}{\mathrm{CrO_4}}$; from this it would be expected that the same phenomena would appear on different scales in the two cases. In the experiments with K_2CrO_4 the range of concentrations was N/250 to N/150000, whereas with $CuSO_4$ it was only N/1.6 to N/748.

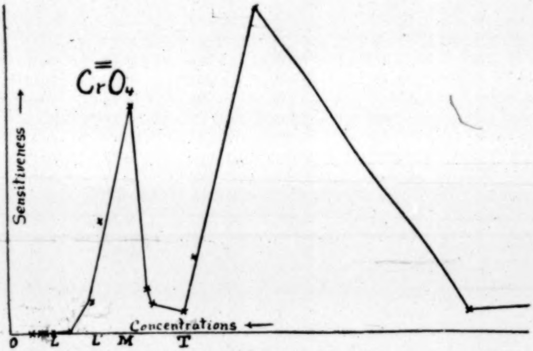

Fig. I.

The results in Table II., when amplified as in the following table, Table III., show:

1. The ratio between the amount of copper that just suffices to produce an appreciable difference in color in 50 cc. of each solution and the total amount of copper present in 50 cc. of the solution at the different coucentrations studied, a relation represented in the table by Δ/β'.

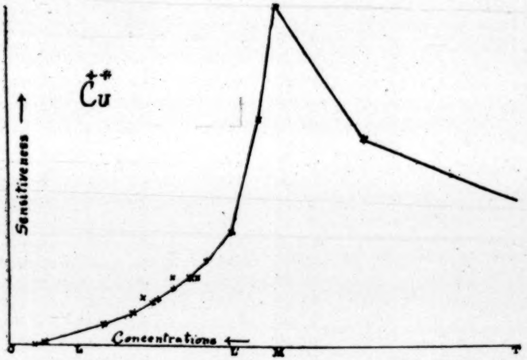

Fig. II.

2. The ratio between the total amounts of copper in two 50 cc. tubes containing solutions that exhibit the minimum perceptible difference in color, a relation represented in the table by β/β'.

In Table III. the experiments are numbered and given in the same order as in Table II.

Table III.—Copper Sulphate Solutions.

1. Number of experiment.	2. Milligrams Cu; total in 50 cc. of solution. β.	3. Milligrams Cu producing just perceptible difference in color in 50 cc. Δ.	4. $\beta + \Delta = \beta'$.	5. Δ/β'.	6. Variation from mean in experiments 3-14, inclusive.	7. β/β'.	8. Variation from mean in experiments 1-14, inclusive.
1	1931.3	154.51	2085.81	0.07		0.93	+0.01
2	965.6	77.25	1042.85	0.07		0.93	+0.01
3	130.2	12.36	142.56	0.09	0.00	0.92	0.00
4	83.7	8.03	91.73	0.09	0.00	0.91	—0.01
5	69.5	5.41	74.91	0.09	0.00	0.93	+0.01
6	60.5	6.18	66.68	0.09	0.00	0.91	—0.01
7	57.2	5.79	62.99	0.09	0.00	0.91	—0.01
8	46.4	3.86	50.26	0.08	—0.01	0.93	+0.01
9	45.8	4.63	50.43	0.09	0.00	0.91	—0.01
10	38.7	3.86	42.56	0.09	0.00	0.91	—0.01
11	37.1	3.86	40.96	0.09	0.00	0.91	—0.01
12	34.8	3.86	38.66	0.10	+0.01	0.90	—0.02
13	30.9	3.09	33.99	0.09	0.00	0.91	—0.01
14	24.7	2.32	27.02	0.09	0.00	0.92	0.00
15	19.3	1.16	20.46	0.06		0.94	
16	17.0	0.77	17.77	0.04		0.96	
17	9.7	1.74	11.44	0.15		0.85	
18	4.3	1.93	6.23	0.31		0.69	

Through a wide range of concentration the values of Δ/β' and β/β' are approximately constant. The variations from the average values, columns 6 and 8, probably represent necessary errors in our experiments. If we had maintained the same conditions as to illumination and use of the eyes prior to each experiment, the errors might have been reduced. Our intention, throughout, was to work under conditions that generally prevail in the laboratory practice of colorimetric analysis. That the errors have very little effect on the form of the graph is readily seen from the relative positions of the points and line in Figure II.

Discussion of Results.

The agreement in form in the curves that are the first parts of the graphs show that the relations set forth by the curves are the same in both cases. For the special case of copper this relation may be stated in several ways, depending on what part of the results we emphasize.

1. If we consider the ratio Δ/β' the following is true:

The amount of copper that will produce, at different concentrations, a difference in color that can just be distinguished is not a constant weight, but *is a constant fraction of the total weight of copper present.* Exceptions occur when the solutions are too dilute or too concentrated.

2. If we consider the ratio β/β', the following is true :

Whenever the difference in color between copper solutions is estimated as just perceptible, the ratio between the two quantities of copper in the solutions compared is always the same. That is,

$$y' - y = k\,\beta'/\beta$$

where y' and y represent two sensations that are just distinguishable, corresponding to two weights of copper β' and β.

3. If we consider the variations of the sensitiveness, S, column 4, Table II, with the total copper, the following is true:

$$\beta S = \beta_1 S_1 = \beta_2 S_2 = \beta_n S_n = \text{constant.}$$

The product of the sensitiveness into the total copper is a constant; or, in other words, *the sensitiveness varies inversely as the total copper.*

We are aware of no changes that occur with dilution, in solutions such as we have worked with, that account for the variations in sensitiveness.

Application to Colorimetric Analysis.

There are reasons for believing that the relation which holds in the two cases studied is a general relation throughout the whole field of colorimetry. The actual effect of the variation of sensitiveness with concentration upon the results obtained in any colorimetric analysis may, then, be stated in a general way; exact statements cannot be made until each colorimetric method has been examined. This effect would, presumably, be most significant in the field where colorimetry finds its proper application,—that is, where minute amounts of substances must be determined quantitatively, as in water analysis.

In general, the following statements are true:

1. Every colorimetric method possesses at least one maximum of sensitiveness.

At concentrations between L and L′ in the graphs Figs. I and II, the relation

$$\beta S = \beta_n S_n$$

holds, and the curve for sensitiveness is a rectangular hyperbola. As dilution progresses a limit L′ is reached where this relation ceases to hold. That this must be true is clear, for otherwise the sensitiveness could become *infinitely* great. That it does not do this is evidenced by Experiments 15 and 16 Table I, and 19 Table II. They show that a point is reached by dilution where the solution no longer *appears* colored, although it still contains colored solute.

At or beyond the point where the relation

$$\beta S = \beta_n S_n$$

ceases to hold, the sensitiveness suddenly acquires much lower values, as can be seen from Tables I and II, column 4, or from the two graphs. The corresponding sudden change in direction, or break in the curve marks the maximum of sensitiveness.

2. Solutions may be too concentrated for accurate colorimetric analysis. These correspond to concentrations between the origin O, and L, a limit above which the solutions are too deeply colored. Our results for Δ/β' show where L is located, and this limit has, in most cases, been discovered by experience, as is indicated by the general practice of avoiding the use of deeply colored solutions.

3. As long as the analyst works at concentrations between the limits L and L′, it is a matter of indifference what concentration he may select for work. The percentage error will be the same in all cases. This is probably why the relations we

have pointed out have hitherto been overlooked; usually the analyst has by accident selected concentrations that lie between the limits L and L′.

That the percentage error is always the same at concentrations between these limits L and L′ is readily seen from the following examples. In these we assume all the concentrations discussed to lie between L and L′, and we assume the value of the fraction Δ/β' to be 0.1. The whole specimen for analysis contains 1 gram of colored substance, and all of it is brought into solution.

Example (*a*).

The specimen is dissolved and the solution diluted to 500 cc. The comparisons are made in 50 cc. Nessler cylinders. The experimental error may then be 0.1 of 50/500 of 1 gram, or 0.01 gram in 50 cc.

In calculating the whole amount of colored substance found by this analysis, the error will be multiplied by 10, or will amount to 0.1 gram in the whole 500 cc.; that is, to 0.1 gram in the whole 1 gram; or, to 10 per cent.

Example (*b*).

The total volume of the solution of the specimen is 50 cc. The error then may be 0.1 of 1 gram or 0.1 gram in 50 cc.; that is, 0.1 gram in the whole 1 gram, or 10 per cent.

Example (*c*).

The total volume of the solution of the specimen is 2 liters. The error then may be 0.1 of 50/2000 of 1 gram or 0.0025 gram in 50 cc.

In calculating the whole amount of colored substance found by the analysis, this error will be multiplied 40 times, and will amount to 0.1 gram in whole 2 liters; that is, to 0.1 gram in whole 1 gram; or, to 10 per cent.

4. There is an advantage in colorimetric analyses in working between the limits L′ and M, that is, at concentrations lying near that of maximum sensitiveness.

This can be illustrated by the case of copper. Suppose, for simplicity, that the whole amount of specimen dissolved contains 1 gram atom, 63.6 grams of copper.

In one case suppose this material is dissolved in 50 liters.

One cylinder will then contain 50/50000 of 63.6 grams, or 0.0636 gram of copper, and the error under consideration may amount to 0.09 × 0.0636 gram, or 0.00572 gram in 50 cc. This is 5.72 grams in 50 liters, containing all the copper, or 8.9 per cent error.

In a second case suppose the same amount of material is dissolved in 187 liters.

One cylinder will contain 50/187000 of 63.6 grams, or 0.017 gram copper, and the error may amount to 0.04 × 0.017 gram, or 0.000681 gram in 50 cc. This is 2.54 grams in 187 liters containing all the copper, or 4.0 per cent.

The percentage error has been reduced by more than half, by working near the concentration of maximum sensitiveness, instead of working at some concentration within the limits L L′.

5. Solutions may be too dilute for accurate colorimetric work. It is scarcely necessary to do more than call attention to the values of the fraction Δ/β' in Experiments 17 and 18, Table III. They are 0.15 and 0.31 instead of the value 0.09 that holds between the limits L L′, and instead of 0.04 that holds at the maximum of sensitiveness. The percentage error corresponding to the fractions 0.15 and 0.31 are about 15.2 per cent and 31.3 per cent, respectively.

Method of Experiment.

The values for the sensitiveness have been obtained by a more direct method in this case than in that of solutions of $\overset{=}{\mathrm{CrO}_4}$. In applying this method in any case, the following procedure is adopted:

1. Make a rough approximation, by the method of comparison and dilution usual in colorimetry, to the limiting amount of colored solute producing a sensible difference in color at some selected concentration. Let us suppose that by this method it is found that 24 cc. of a standard colored solution "S," when put into a 50 cc. Nessler cylinder with 26 cc. of water, gives a solution that can be distinguished with difficulty from one containing 25 cc. of "S" and 25 cc. of water. The difficulty in the distinction is so great as to make it doubtful.

2. The next step is to decide whether or not 1 cc. of "S" does produce a perceptible difference in 50 cc. of the above solutions. To this end prepare a series of tubes marked, let us say, J, K, L, M, N, O and P, respectively, and introduce into them the following volumes of "S" and of water:

	J.	K.	L.	M.	N.	O.	P.
Volume of "S"	28	27	26	25	24	23	22
Volume of water	22	23	24	25	26	27	28

After the contents of the cylinders have been *thoroughly* mixed and each cylinder has been slipped into a black paper jacket, mix the cylinders until their identities, as indicated previously by their relative positions, are lost, and then arrange them in the order of their apparent intensities of color. After they had been thus arranged, if they are found, always to be arranged in the alphabetical order, three to ten times, it is obvious that 1 cc. of "S" produces in 50 cc. of solution a difference in color that is unmistakably perceptible. The concentration to which this result applies is the average concentration of the series of solutions, that is, the concentration of solution in tube M.

3. In the first experiment by 2, it often happens that the tubes at one end of the series are arranged by color in the proper order, while those at the other end are confused. Thus, M, N, O, P may be correctly arranged, while J, K and L are confused. This indicates that the colors of the solutions in J, K and L are too deep for 1 cc. of "S" to produce an appreciable change in them. In such a case put J, K and L aside and introduce into the series Q, R and S, containing

	Q.	R.	S.
Volume of "S"	21	20	19
" " water	29	30	31

Mix the tubes and arrange according to intensity of color. The ability to arrange the series repeatedly in the alphabetical order indicates that the quantity, 1 cc. of "S," is sufficient to produce a perceptible difference at the concentration of solution in the middle tube of the new series, that is, in P.

In other cases, when the lower tubes of a series are sometimes confused, the reverse procedure is adopted.

The process of substituting tubes and thus lowering or raising the average concentration, while retaining the same difference in concentration, is continued, if necessary, until a series of tubes is obtained showing unmistakable differences in color.

4. In other cases it may be recognized, in the first approximation, that the ease in making the distinctions is relatively great. In these circumstances, select L, M, N from the series and add to them 4 additional tubes to form the following new series :

	KL.	L.	LM.	M.	MN.	N.	NO.
Volume of "S"	26.5	26	25.5	25	24.5	24	23.5
" " water	23.5	24	24.5	25	25.5	26	26.5

If this series is arranged by color readily in its alphabetical order, select from it LM, M, MN and add new tubes to form the following series :

	LLM.	LM.	LMM.	M.	MMN.	MN.	MNO.
Volume of "S"	25.75	25.50	25.25	25	24.75	24.50	24.25
" " water	24.25	24.50	24.75	25	25.25	25.50	25.75

By following (3) and (4), separately or combined, as occasion demands, it is possible to arrive directly at the difference in weight of colored solute just detectable at an average concentration that is known.

A Possible Interpretation of the Results.

Our results are strongly suggestive of the psychophysical law known as Weber's Law. One assumption must be made in order that our results may be compared with the law, it is that the strength of the stimulus producing the sensation of blueness, caused by light that has passed through a tube of solution to the eye, is directly proportional to the quantity of copper contained in the solution. This assumption seems to us almost axiomatic.

With respect to the first relation, represented by

$$\frac{\Delta}{\beta'} = \text{constant},$$

we have the two following statements for comparison :

The amount of copper that produces, at different concentrations, a difference in color that can just be distinguished is a constant fraction of the total weight of copper present (*vide* p. 201).

The increment in stimulus that produces a just perceptible difference in sensation is always the same fraction of the total stimulus (Weber's Law).

With respect to the second relation, represented by

$$y' - y \;=\; k\beta'/\beta,$$

we have for comparison these two statements :

Whenever the difference in color between two copper solutions is just perceptible, the ratio between the two quantities of copper in the solutions is always the same (*vide* p. 201).

A difference between any two sensations will be estimated as equally perceptible if the relation between the stimuli is the same (Weber's Law).

On the assumption indicated, the statements in each pair are identical.

Weber's Law applies very closely to our results within the limits of concentration L and L′. From the limit L′ to the point near T, where the sensation of color disappears, the law is not valid.

As our results are independent of Weber's Law, we have no intention of entering the discussion of its merits. Our main interest in the law arises from the fact that if, as stated by certain authorities, von Helmholz[1] for example, it holds for the sensitiveness of the eye for mean degrees of intensity of sensation, there can be no doubt that the relation we have found in the colorimetry of $\overset{=}{CrO_4}$ and $\overset{++}{Cu}$ is a perfectly general one throughout colorimetry.

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[1] "Popular Lectures" translated by Atkinson, Series 2, pp. 101–6. Compare von Helmholtz: "Handb. der Physiologischen Optik," 2 ed., 1896, 387, 683. Fechner, G. T.: "Elemente der Psychophysik," 2 ed., 1889, II., 1. Wundt, W.: "Grundzüge der Physiologischen Psychologie," 5 ed., 1902, I., 493. Köhler: A.: "Ueber d. hauptsächlichsten Versuche eine math. Formulirung des p. p. Gesetzes von Weber," Philosophische Studien, 1886, 3, 572.

Chemical Laboratory,
Bryn Mawr College,
May, 1906.

ON THE PREPARATION OF THE CYANAMIDES.

By Ralph H. McKee.

In the study of another problem, it became necessary to prepare the mono- and dialkyl cyanamides in quantity. Examination of the literature brought to light a number of methods, but each is subject to criticism, being either troublesome and tedious in application,[1] or using, as one of the starting materials, a substance difficult to prepare and not on the market.[2] The yields also are unsatisfactory; in general the amines are used as the starting material and considerably less than one-half is transformed into the corresponding cyanamides.[3]

A general method has now been found by which the amines can be changed quickly and easily, nearly molecule for molecule, into the corresponding cyanamides. It is the purpose of the present paper to discuss this general method and the modifications necessary in a few special cases. The applicability of the method to the transformation into cyanamides of acid amides and of amines containing ring groupings will also be pointed out.

The preparation of the dialkylcyanamides may be typified by the preparation of dipropylcyanamide:

Dipropylcyanamide, $(C_3H_7)_2NCN$.—Twenty and two-tenths grams (1 mol.) of dipropylamine were added to a solution of 69 grams (4.5 mol.) of potassium cyanide, in 200 cc. water, and to the whole, kept below 15°, there was added, in about 1 cc. portions, a solution of 11 cc. (1.1 mol.) of bromine, in 60 cc.

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[1] Cahours und Cloez: Ann. Chem. (Liebig), **90**, 95 (1854). Chancel: Compt. rend., **116**, 329 (1893). Berg: Ann. de Chimie (7), **3**, 352 (1894). Wallach: Ber. d. chem. Ges., **32**, 1873 (1899).

[2] Hofmann: Ber. d. chem. Ges., **2**, 602 (1869); **3**, 264 (1870); **18**, 2784 (1885). Fileti und Schiff: *Ibid.*, **10**, 428 (1877). Braun: *Ibid.*, **33**, 1451 (1900). Braun und Röver: *Ibid.*, **36**, 1196 (1903).

[3] Erlenmeyer: *Ibid.*, **14**, 1868 (1881). Kaess und Gruszkiewicz: *Ibid.*, **35**, 3598 (1902).

of low boiling ligroin. During the addition of the bromine solution the flask was shaken so that the dipropylamine hydrobromide formed might be decomposed by the potassium cyanide solution and the dipropylamine set free to be further acted upon by the bromine and potassium cyanide. The ligroin solution was separated from the aqueous liquid, washed with dilute sodium hydroxide, dried with calcium chloride, the ligroin distilled off and the oil remaining in the flask fractionated *in vacuo*. The yield was 23.5 grams, boiling exactly at 95° (11 mm.) This is over 93 per cent of the theory. The total time consumed, including 20 minutes' drying of the ligroin solution, was just 2 hours.

It is best to carry out the operation in a hood, as there is some hydrocyanic acid set free during the addition of the bromine solution and some during the removal of the solvent by distillation, the washing with sodium hydroxide failing to remove all the dissolved gas.

By the preparation[1] of methyl dipropylisourea from it the identification of the oil was made complete.

Asymmetrical Methyldipropylisourea, (Methyl Imidodipropylcarbamate), $(C_3H_7)_2NC(:NH)OCH_3$.—A methyl alcoholic solution of dipropylcyanamide (1 mol.) was treated with a methyl alcoholic solution of sodium methylate (1.1 mol.), the whole heated to 65° for 1.5 hour, the cooled solution made acid with hydrochloric acid and allowed to stand until the small amount of isonitrile, formed as a by-product, had been decomposed. This solution was extracted with ether, to remove any unchanged dipropylcyanamide, and then made alkaline with strong alkali and the separated isourea ether taken up with ether. The ether solution was washed with water, dried with anhydrous sodium sulphate, the ether distilled off and the remaining oil fractioned *in vacuo*. Yield 80 per cent of the theory. Boiling point 98° (19 mm.) and 203° (748 mm.). Density at 22°, referred to water at 4° (Westphal) 0.9103. Methyldipropylisourea is much more soluble in cold than in warm water. An approximate determination of its solubility gave 3.5 parts at 15°, and 1.5 parts at 50°, in 100 parts of water.

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[1] Cf. McKee: This Journal, 26, 236 (1901).

Analysis (Kjeldahl-Gunning). Found, 17.82 per cent; calculated for $C_8H_{18}N_2O$, 17.74 per cent nitrogen.

This is the first known oxygen ether of the ureas having two aliphatic groups attached to nitrogen. It is also the first isourea to boil at atmospheric pressure without decomposition; even the mother substance, methylisourea, $NH_2C(:NH)OCH_3$, from which the present isourea is derived, decomposes on attempting to distil it under atmospheric pressure.[1]

Diisobutylcyanamide, $(C_4H_9)_2NCN$, was prepared in the same manner as dipropylcyanamide. The yield was 83 per cent, boiling at 123° (25 mm.).

Diisoamylcyanamide, $(C_5H_{11})_2NCN$, was obtained by the same method in a yield of over 92 per cent of the theory. Diisoamylamine hydrobromide is soluble to the extent of less than 3 parts in 100 parts of water at 15°, and is practically insoluble in ligroin. In order to liberate the amine from its slightly soluble hydrobromide, by the action of the weakly alkaline potassium cyanide solution, it is necessary to shake long and vigorously, thereby doubling the time required for the preparation of the cyanamide. Diisoamylcyanamide boils at 134° (14 mm.).

Diethylcyanamide, $(C_2H_5)_2NCN$.—Ethyl acetate is to be preferred to ligroin as a solvent when the molecular weight of the desired substance is small, or when the amine used, or cyanamide formed is but slightly soluble in ligroin. The reaction can be the easier controlled if the amine is diluted with several times its volume of ethyl acetate before adding the ethyl acetate solution of bromine.

Using a temperature of about 5° during the addition of the bromine solution, diethylcyanamide, boiling at 188°–189° (748 mm.), was obtained in good yield. Its identification was made complete by the formation from it of methyldiethylisourea.

Methyl(asym)diethylisourea (*Methyl Imidodiethylcarbamate*), $(C_2H_5)_2NC(:NH)OCH_3$, was prepared by the same method as the methyldipropylisourea. It boils at 171°–172° (745 mm.). It distils with water, benzene and even ether vapor. Methyldiethylisourea is a strong monacid base and may be titrated with hydrochloric acid. Using 0.1 N hydrochloric acid and methyl orange, 0.4412 gram required 33.87 cc.; calculated for $C_6H_{14}N_2O$, 33.88 cc.

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[1] McKee: This Journal, **26**, 248 (1901).

Dimethylcyanamide, $(CH_3)_2NCN$, was prepared in the same way as the corresponding ethyl compound, but the yield was very small. The low yield was found to be due to the fact that the cyanamide formed is much more soluble in water[1] than in ethyl acetate. By carrying out the preparation in the presence of but a trace of water, a yield of over 50 per cent of the pure dimethylcyanamide was obtained.

To an ethyl acetate solution of dimethylamine (1 mol.) a few drops of water were added, then powdered potassium cyanide (4 mol.) and an ethyl acetate solution of bromine (1.1 mol.) was run in slowly and with continued shaking. The temperature was 10°–15°. The solution was filtered from the solid, dried, the solvent distilled off and the oil fractioned. The pure substance boils at 98° (104 mm.) and at 164° (740 mm.).

Methylcyanamide, CH_3NHCN, was prepared in the same way as dimethylcyanamide, except that care was taken to prevent polymerization to the melamine, by keeping the temperature below 0° during the addition of the bromine solution. By using a partial vacuum the ethyl acetate was distilled off at a temperature below 40°. From the crude methylcyanamide remaining after distilling off the ethyl acetate, fairly pure methylcyanamide may be obtained by extracting with a little absolute ether and evaporating the ether extract. The yield is poor, 30 per cent, but apparently it is as good as by the other methods[2] given in the literature.

The ethyl acetate solution of methylamine must be used at once after its preparation, as otherwise there is considerable loss due to the interaction of the amine and solvent. A solution which showed 9.5 per cent of methylamine by titration, after standing over night, at room temperature, contained only

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[1] Cf. Braun und Röver: *Loc. cit.*

[2] Cahours und Cloez: *Loc. cit.* Cf. Erlenmeyer: *Loc. cit.* Kaess und Gruszkiewicz: *Loc. cit.* Hofmann: Ber. d. chem. Ges., 3, 264 (1870).

1 per cent of methylamine which had not reacted with the solvent.

The methylcyanamide was identified by its change, on heating, to isotrimethylmelamine, which, after washing with water and drying on a clay plate, melted at 123°–124° when quickly heated, then solidified and finally remelted 50° higher. Freund und Schwarz[1] give this melamine as having the double melting point of 123°–124° and 179°.

Ethylcyanamide, C_2H_5NHCN, was prepared from ethylamine in the same way as methylcyanamide from methylamine, but the yield, 71 per cent, was much better than with the methyl compound.

Isoamylcyanamide, $C_5H_{11}NHCN$, was prepared, in good yield, by treating an ethyl acetate solution of isoamylamine (1 mol.) with a concentrated, aqueous solution of potassium cyanide (4 mol.) and to the whole, kept at from 5°–10°, an ethyl acetate solution of bromine was slowly added with shaking. The ethyl acetate was separated from the water solution, washed with water, extracted with strong, 30 per cent sodium hydroxide, the resulting alkali solution cooled and made slightly acid with acetic acid, which caused an evolution of hydrocyanic acid, and the oil which separated was taken up with ether. The ether solution was washed several times with water, dried with calcium chloride and evaporated *in vacuo*, over concentrated sulphuric acid. A slightly colored oil remained which showed the properties of the monoalkylcyanamides. The oil was analyzed without further purification: Found, 24.46 per cent of nitrogen (Kjeldahl-Gunning); calculated for $C_6H_{12}N_2$, 25.03 per cent.

Attempts made to prepare cyanamides in a similar manner from amines, such as aniline, ethylaniline, etc., having the nitrogen atom attached directly to the benzene ring, were not successful. However, it was found that the method was readily applicable to the preparation of the corresponding cyanamides from benzylamine and piperidine.

Benzylcyanamide, $C_6H_5CH_2NHCN$, was prepared in the same way as isoamylamine except that the crystals, which separated from the alkali extract on adding acetic acid, were not taken up with ether, but instead were at once filtered off and dried on a clay plate.

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[1] Ber. d. chem. Ges., **29**, 2498 (1896).

The crystals gave a melamine on heating, or by standing at room temperature and had the solubilities given by Strakosch,[1] but, instead of melting at 33°, they melted at 43°. Strakosch crystallized the benzylcyanamide from ether and, as the cyanamide is *extremely* soluble in ether, it is probable that the low melting point of his product was due, in part, to traces of that solvent persistently held by the cyanamide. The yield was 90 per cent of the calculated.

Cyanpiperidine, $C_5H_{10}NCN$.—This was prepared in the same way as diethylcyanamide. The yield was 80 per cent, boiling at 102° (11 mm.). Analysis:

I. 0.1186 gram substance gave 26.45 cc. moist N at 17° and 746.4 mm.

II. 0.1092 gram substance gave 24.55 cc. moist N at 19°.5 and 749 mm.

	Calculated for $C_6H_{10}N_2$.	Found. I.	II.
N	25.49	25.51	25.52

Tests of the method, using acid amides, $RCONH_2$, instead of basic amines, RNH_2 and R_2NH, failed to give the acyl cyanamides, RCONHCN, desired.

Lake Forest University,
Lake Forest, Illinois.

REPORT.

Tautomerism and Steric Hindrance.

At intervals during the past two years E. C. C. Baly, in conjunction with other chemists, has published a series of papers[2] containing the results of measurements of the ultraviolet absorption spectra of various organic compounds. From these observations they have deduced certain theoretical conclusions which are interesting and may prove to be of considerable importance in modifying the current views regarding tautomerism and steric hindrance. The spectra were determined in the ordinary manner, except that the source of illumination was an arc light between iron poles. This arrangement had several advantages, the chief one being the large number of lines, which enabled the absorption bands to be measured with greater ease, and possibly with greater accuracy than had heretofore been the case.

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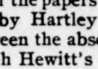
[1] Ber. d. chem. Ges., **5**, 694 (1872).

[2] J. Chem. Soc., **85**, 1029 (1904); **87**, 766, 1332, 1347, 1334 (1905); **89**, 489, 502, 514, 618, 966, 982 (1906).

The earlier experiments were carried out with acetylacetone, ethyl acetoacetate and certain of their derivatives, and it was found that neither the pure ketonic nor the pure enolic form of these compounds gives an absorption band but that a band is strongly developed when the two tautomeric forms of the ketone are present in equilibrium with one another. Thus, to take the case of ethyl acetoacetate, selective absorption is not due to the presence of either the form $CH_3COCH_2CO_2C_2H_5$, or the form $CH_3C(OH) : CHCO_2C_2H_5$, but to both. Further, the absorption cannot be due to the wandering of the labile atom because the oscillation frequency of the light waves absorbed is practically the same whether this wandering atom be hydrogen, beryllium, sodium, or thorium. Moreover, it is impossible to draw any comparison between the oscillation frequencies of this labile atom and those of the light waves absorbed. These facts lead to the conclusion that the absorption of light is due to the *change of linking* indicated by the equation $—CH_2CO— \rightleftarrows —CH : C(OH)—$. The same idea may be expressed in another way by saying that in the passage from the ketonic to the enolic form and *vice versa*, the intermediate, transition phase  $—\underset{\text{H}}{\text{CH}}\underset{\underset{\text{O}}{|}}{\text{C}}—$ must have a momentary existence, *i. e.*, there must be an instant when the hydrogen, or other labile atom, is not linked to either carbon or oxygen and when both the carbon and oxygen linkages are undergoing rearrangement. The term *isorropesis* is applied to such oscillation. This theory appears to be in harmony not only with the results recorded in the papers under consideration, but also with those obtained by Hartley and others who have studied the connection between the absorption of light and change of linkage and also with Hewitt's theory of fluorescence.

A considerable number of other enol- keto- tautomerides, besides the two already mentioned, have been investigated by Baly and the work was then extended to the aromatic compounds. Hartley and Huntington[1] had observed 7 absorption bands in benzene, but Hartley and Dobbie[2] could only detect 6. Baly is able to confirm the presence of 7 bands, which he regards as being due to the making and breaking of carbon linkages in benzene. If it be assumed that an even number only of carbon atoms are concerned in these changes, then not more than 7 transition phases are possible, *viz.*, 3 where two carbon atoms are concerned (*o*-, *m*- and *p*-), 3 when four carbon atoms are acting and 1 when all six of the carbon atoms change. This change in the linkages is supposed to be similar in all respects to that involved in the ketonic-enolic isomerism mentioned above.

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[1] Phil. Trans., **170**, i, 257 (1879).

[2] J. Chem. Soc., **73**, 695 (1898).

The absorption of a considerable number of substitution products of benzene was determined and various regularities were observed, of which the following may be mentioned. The substitution of hydrogen by a single alkyl group produces an absorption which shows the first 2 benzene bands, the position of the remaining 5 being occupied by a single broad band. Other substituents produce greater changes. Of the derivatives of benzene with two saturated substituent groups, the para compounds are to be regarded as the most symmetrical, or, to put it in another way, the internal motions of the benzene molecule are less disturbed by para than by ortho or meta substitution.

In the third series of papers the subject of steric hindrance is taken up. This hypothesis was first brought into prominence by v. Meyer, who found that the esterification of diortho substituted benzoic acids, by means of alcohol and hydrogen chloride, became increasingly difficult as the mass of the substituent increased. The same has been found to be true of other reactions such as the hydrolysis of esters, nitriles, etc. On the other hand, Stewart[1] has shown recently that when a hydrogen atom near the carbonyl of a ketone is replaced by methyl there results a decrease in the additive capacity of the carbonyl group. This is what would be anticipated from the hypothesis of steric hindrance and yet there are difficulties against the acceptance of the latter idea. Thus, if a carbethoxy group, $—CO_2C_2H_5$, is substituted for hydrogen in the ketone, the additive power of the latter is increased and yet the mass of carbethoxy is nearly five times that of methyl. Experiments on the additive action of sodium hydrogen sulphite show that ketones which are semi-enolized react much more readily than those in which the carbonyl is intact. Further, the ortho disubstituted acids, which do not react with alcohol and hydrogen chloride, readily yield esters when their silver salts are treated with alkyl haloids, and yet it is not easy to regard the conditions of reaction as more drastic in the latter than in the former case. As stated above, the *change* from the enolic to the ketonic form produces an absorption band in the ultra-violet, and this band is found to decrease proportionately to the diminution in the reactivity of the carbonyl group of the ketone.

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[1] J. Chem. Soc., 87, 185 (1905).

An examination of a number of α-diketones, such as diacetyl, indicates that their yellow color is due to isorropesis between the carbonyl oxygen atoms in juxtaposition, the absorption being in the blue region of the spectrum. In general, the conclusion is reached that *it is quite untrustworthy to assume any fundamental difference in the constitution of compounds because one is colored and the other is white.* It is possible that color and fluorescence are both evidences of isorropesis; in the former case the isorropesis provides the mechanism and incident light actuates it; in the latter case isorropesis both provides and actuates the mechanism.

Similar results are obtained with the three nitroanilines and the three nitrophenols in neutral solution, and *p*-nitrophenol in alkaline solution. Under such conditions all these compounds have the quinonoid structure. Some interesting suggestions regarding the nature and configuration of the benzene ring are offered, but space is not available for their reproduction.

A later paper deals with the reactivity of substituted quinones. The results lead to the conclusion that the effect of substitution is to diminish potential tautomerism and thus, indirectly, isorropesis, while by unevenly loading the ring it produces, in benzoquinone, a greater tendency to assume the benzenoid form.

The last two papers hitherto published deal with isonitroso compounds and the phenylhydrazones of simple aldehydes and ketones, respectively, the results being of the same general character as those described above.

The idea of steric hindrance appears to be doomed; it has never been a very satisfactory hypothesis, partly from its rather crude mechanical nature and partly because there was a great temptation to use it to cover our ignorance of real causes and facts. Evidence against it of a purely chemical nature has been accumulating during the past few years, thus, for instance, the difficulty in obtaining the higher phenylated derivatives of methane, ethane, etc., has been shown to be simply a question of the method employed. A further point brought out in the papers under review is the fact that ketones apparently owe their reactivity to the presence of an enolic group, $:C(OH)—$ or, at any rate, to what may be termed a "nascent," rather than a stable carbonyl group. The writer of this report has been engaged for a considerable time on the investigation of camphoroxalic acid, by purely chemical methods. The results all point to the fact that the reactive group in this compound is the enolic : C(OH)— in the side chain, the true carbonyl of the original camphor nucleus being relatively very inert. It is interesting to have this view supported by conclusions obtained from experiments and properties entirely physical in their nature.

J. BISHOP TINGLE.

REVIEWS.

INTRODUCTION TO GENERAL INORGANIC CHEMISTRY. By ALEXANDER SMITH, Professor of Chemistry and Director of General and Physical Chemistry in the University of Chicago. New York: The Century Co. 1906. Price, $2.25.

Text-books of inorganic chemistry for beginners usually contain 400 to 500 pages, and we may assume that this space is deemed sufficient, by the majority of teachers, for treatment of the matters absolutely essential to the beginner.

This book contains 780 pages, and a cursory examination will convince most teachers that it is too difficult for the average college student, taking the beginners' course, without previous training in science, although the author argues for such use. It should rather be ranked in the class of the larger text-books suitable for students who have some knowledge of the elements of chemistry and who have already done a little laboratory work.

A consideration of the modern text-books of this class shows that their authors employ the excess of space over the three or four hundred pages of essentials in widely differing ways. One discusses physical-chemical phenomena at great length. Another is mainly descriptive, and gives the latest methods of chemical manufacture and illustrated descriptions of improved apparatus in considerable detail. Other writers give much space to the study of constitution and to complex structural formulas. Finally, the use of the French text-books would lead the student to think that thermo-chemistry was the only chemical theory worthy of consideration. Now all of these books, without an exception, are very good in their way, are very interesting to chemists and repay fully the study bestowed on them by those who have some all-round knowledge of chemistry and chemical theory. We must not forget, however, that these books are not primarily written for our pleasure, but as the text-book for students, and that in most cases the text-book is the only book on chemistry which the average college student seriously reads; hence he learns to regard chemistry from one aspect alone; nor is this corrected by the lectures, as the teacher generally chooses a text-book which mirrors his own way of teaching.

It is, therefore, with a feeling of great satisfaction that we find that Professor Smith's book cannot be classed in any one of the categories enumerated, but includes somewhat of them all. It is not a book to be lightly passed over. It is evident that the writer has given deep thought and great labor to the due apportionment of theory and fact, to the selection of theoretical matter, and to its introduction at the proper place. Quotations from the preface best explain Professor Smith's position.

"The principles of chemical equilibrium are (and have been for the past half-century) fully as much required for intelligent consideration of the simplest experiment, as is the theory of combining proportions itself. Important parts of the theories of solutions and of the battery are much more recent, but each is equally indispensable to the understanding of matters which cannot long be withheld from the notice of the beginner. Surely space ought not to be saved by entire omission of essential parts of the chief thing which makes chemistry at all worthy of a place among the sciences. Nor may we attain brevity, no matter how great the temptation, by condensing the passages on theory until they reach the limit of comprehensibility by an expert. Without clear exposition, full illustration and frequent application, laws and principles simply repel, or worse still mislead the beginner.

"The order of topics was determined by many considerations jointly. For example, in the first week of his work, a student may encounter experiments, in connection with which almost every part of chemical theory might usefully be discussed. But mastery of the theory must necessarily come bit by bit, and the theory is, therefore, distributed through the book. Instead of being introduced as soon as a fragment offers a chance for explanation, the treatment of each of the various theoretical subjects, as far as possible, has been postponed until a whole chapter could be devoted to it. The result makes subsequent reference easier and facilitates alterations in the order of study."

In the opinion of the reviewer, Professor Smith has succeeded in his task and has produced the best modern text-book on general chemistry for advanced students thus far published. University and college teachers should examine it.

By leaving but a narrow margin to the page, and using thin but opaque and tough paper, the publishers have made the book not too thick and of convenient size. E. R.

EINFÜHRUNG IN DIE THERMODYNAMIK AUF ENERGETISCHER GRUNDLAGE. Von DR. JULIUS MEYER. Halle: Knapp. pp. 216. 1906. Price, M. 8.

In the preface of this most recent text-book on Thermodynamics the author states that he has designed it specially for students of chemistry and physical chemistry, and that his object in producing a new text-book, in a field where there already exist so many excellent works, is to offer one which is based on the reality of energy, and which is free, as far as possible, from matter which is not of special interest to the students concerned. The outline of the book is what one would expect, beginning with a discussion of energy, temperature and equations of state, and proceeding through the first and second principles of thermodynamics to various applications of formula to chemical reactions. The scope of the book is not unlike that of Buckingham's excellent treatise on Thermodynamics, and is not as wide as that of Planck's well-known work.

It must be confessed that the writer of the present review is thoroughly out of sympathy with the methods followed in this book. The discussion of energy, of temperature, of the properties of gases and of the second principle of thermodynamics seem to him to be hopelessly wrong. If one is willing to accept the various mathematical formulae and to regard the book as simply a discussion of the applications of these, it meets with the utmost approval. The illustrations taken from chemistry and physical chemistry are well chosen and are in every case the statements of our most recent knowledge. Therefore, as a book of reference for students who wish to obtain information concerning the agreement between theory and observation, it is to be recommended most highly.

J. S. AMES.

HIGHER MATHEMATICS FOR STUDENTS OF CHEMISTRY AND PHYSICS, WITH SPECIAL REFERENCE TO PRACTICAL WORK. By J. W. MELLOR, D.Sc. Second edition enlarged. London, New York and Bombay: Longmans, Green & Co. 1905. pp. 631. Price, $4.50.

The appearance of the first edition of this valuable book has already been noticed.[1] The aim and object of the second edition is seen from the author's preface.

"In this edition, the subject-matter has been rewritten, and many parts have been extended in order to meet the growing tendency on the part of physical chemists to describe their ideas in the unequivocal language of mathematics."

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[1] THIS JOURNAL, **29**, 287 (1903).

The work was most timely, and the reviewer rejoices with the author in finding that there is such a large demand for it. The time has come when chemical facts, or at least a large number of them, can be expressed in mathematical language, and we have seen what magnificent progress has been the result.

This book undoubtedly makes mathematics accessible to a large number who have not the time, and often not the qualification for a more exact and extended study of the several branches of the subject. Further, Mellor has the happy faculty of selecting just those things which the students of the natural sciences ought to know. This is shown not only by the work now under consideration, but by his admirable book on "Chemical Statics and Dynamics."

Students of the natural sciences in general, and of chemistry in particular are urged to work through this splendid book.

H. C. J.

LA GRANDE INDUSTRIE CHIMIQUE. LE CHLORURE DE SODIUM, SEL MARIN, SEL GEMME, LES POTASSES ET LES SOUDES COMMERCIALES. Par H. **PÉCHEUX**, Professeur de physique et de Chimie a l'École Nationale d'Arts et Métiers d'Aix. Avec 26 Figures. Paris: Librairie J. B. Baillière et Fils. 1906. pp. 96. Price, 1.50 Fr.

This is one of twenty-four little books, the collection bearing the title "Encyclopédie Technologique et commerciale, collection nouvelle." If the other twenty-three volumes are like this it will form a unique work, for we have here a semi-popular monograph, written by a French government employee, professor in a national school, and our comment must be that it is incomprehensible that a reputable publisher should dare offer it to the public.

Just think of a monograph on the manufacture of sodium hydroxide, published in 1906, which makes no mention of electrolytic processes, and teaches the reader that the only commercial method is the action of slaked lime on sodium carbonate!

The only reference to the occurrence of salt in America is a line mentioning a deposit of salt in "the Rocky Mountains!" In the table of statistics, America is ignored, and astounding statements are made concerning production in Europe. In the following tables column A copies the figures given in this book of the average yearly production in metric tons. Column B gives the official figures, in short tons, for 1902, taken from the "Mineral Resources of the United States, 1904," published by the U. S. Geological Survey.

	A. Metric tons.	B. Tons.
United States	. . .	3,339,891
Great Britain	2,000,000	2,121,147
Russia	1,500,000	2,035,969
Austria	800,000	575,936
France	750,000	982,479
Germany	600,000	1,745,226

We see that, as a matter of fact, the United States leads the running enormously, Great Britain and Russia are neck and neck, with Germany rapidly gaining on them and France and Austria hopelessly out of the race. In this, as in several other industries, the relative rapid advance of the United States and Germany, as compared with other countries, is noticeable.

Further criticism of this book is unnecessary, but it is only fair to say that if it had been published in 1875 it would have been a respectable and fairly correct statement of the processes of the time, and the statistics would have been tolerably accurate for Europe at that date.

It should be further stated that it is probable that this volume is an unrevised reprint of an old book by a, possibly, dead author, so that M. Pécheux may be guiltless, but the publishers and compilers are inexcusable. E. R.

First Science Book. Physics and Chemistry. By Lothrop D. Higgins, Ph.B., Instructor in Science in the State Normal School. Danbury, Conn. Boston: Ginn & Co. 1906. Price, 65 c.

A serviceable little manual for school use. One hundred and seventy pages are devoted to elementary physics and 58 to chemistry. There are many illustrated experiments, all very simple, which can be performed with little outlay for apparatus. E. R.

Lehrbuch der Gerichtlichen Chemie. By Drs. Georg Baumert, M. Dennstedt and F. Voightländer. In two volumes. Braunschweig: Fr. Viewig und Sohn. 1906. Vol. II. pp. vii + 248 Price, M. 9.

The second volume of this work relates to the detection of forgeries in handwriting, to the examination of blood, etc. The part pertaining to forgeries in handwriting, in its chemical relations, refers particularly to the materials of ink. The inks which are used in old handwritings are described, and naturally the materials used for writings that represent old manuscripts should correspond to the inks in use at the time the manuscript must have been written. The microscopic tests are given in full and illustrated by photo-micrographs. In the chemical tests the behavior of the inks with water and their power of copying with water and with hydrochloric acid, as also their behavior with other chemicals, is described. Special attention is given to their action with acid and alkaline reagents and with bleaching materials. Forgeries with lead pencil are also explained. Methods which are used for the mechanical and chemical removal of inks are described, and also for the mechanical removal of writing made by lead pencil. The methods that are used in determining whether all the writing on a page was made at the same time or at different ones are set forth in detail. An interesting chapter is devoted to means of deciding whether signatures are written by hand or produced by mechanical ways. The methods which should be used to decipher practically illegible writing are given. Processes for determining whether any secret marks—that is, those which are developed under certain conditions—have been used or not, are described.

Of special interest for legal purposes are the chapters devoted to the detection of blood and blood spots. The best methods of making photographs of blood spots are discussed in detail, as well as the peculiarities of blood and its differentiation from splotches of similar character. A very complete statement is made of all the standard methods now practiced for distinguishing between human blood and that of other animals. A chapter is also devoted to the action of poisonous gases on the blood. This volume will be found of particular interest to biological chemists and physiologists, who are called upon as expert witnesses before courts. H. W. W.